Water-Supply and Irrigation Paper No. 162. Series M, General Hydrographic Investigations, 17

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

DESTRUCTIVE FLOODS IN THE UNITED STATES IN 1905

WITH A

DISCUSSION OF FLOOD DISCHARGE AND FREQUENCY

AND AN

INDEX TO FLOOD LITERATURE

BY

EDWARD CHARLES MURPHY
AND OTHERS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1906

Water-Supply and Irrigation Paper No. 162. Series M, General Hydrographic Investigations, 17

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

DESTRUCTIVE FLOODS IN THE UNITED STATES IN 1905

WITH A

DISCUSSION OF FLOOD DISCHARGE AND FREQUENCY

AND AN

INDEX TO FLOOD LITERATURE

BY

EDWARD CHARLES MURPHY
AND OTHERS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1906

CONTENTS.

ILLUSTRATIONS.

DESTRUCTIVE FLOODS IN THE UNITED STATES IN 1905.

By E. C. Murphy and others.

INTRODUCTION.

There were few very destructive floods in 1905. The most remarkable flood or series of floods of the year were those in the Gila River basin in Arizona. From January 15 to April 30 occurred a series of seven floods—almost a continuous flood—remarkable for the total volume of flow. In November there was in this basin another flood, which was remarkable for its magnitude, being the largest on record on Salt River. The other large floods of the year occurred on comparatively small streams. Few lives were lost and the damage was small compared with that of some previous years.

In addition to the credits for data given in the body of this paper the writer desires to acknowledge his indebtedness to F. H. Newell, chief hydrographer, for valuable suggestions; and to James Dun, chief engineer Santa Fe Railway System, who has furnished data and transportation over the Santa Fe lines to flooded sections.

FLOOD ON PEQUONNOCK RIVER, CONNECTICUT.

By T. W. Norcross.

INTRODUCTION.

A flood on this stream on July 29 and 30, popularly known as the Bridgeport flood, destroyed a quarter of a million dollars' worth of property. It was due primarily to a very heavy local rainstorm, during which 11.32 inches of rain fell in seventeen hours at Bridgeport, Conn., where it was heaviest. The flood wave was enlarged by the failure of four dams in the watershed.

The Pequonnock is a small stream that rises in the northeastern part of Fairfield County, Conn., flows south about 14 miles, and empties into Long Island Sound at Bridgeport. Its fall from source to mouth is 460 feet. Its channel is rather narrow, with numerous bends, and its banks are low and flat. Its drainage basin is mainly hilly pasture land, with little timber, and has an area of 25 square miles.

PRECIPITATION.

The following table, prepared from records of the United States Weather Bureau at Bridgeport, shows the precipitation during this storm:

Table showing rate of rainfall at Bridgeport, Conn., July 29–30, 1905.

Time of beginning.	Time of end.	Time elapsed.	Precipitation.	Average rate per hour.
		h. m.		
July 29—11.40 a. m.	1.30 p. m.	1. 50	0. 10	0. 06
1.30 p. m.	4.15 p. m.	2. 45	5. 90	2. 15
4.15 p. m.	7.50 p. m.	3. 35	4. 18	1. 17
7.50 p. m.	12.00	4. 10	0. 77	0. 18
July 30—3.00 a. m.	5.20 a. m.	2. 20	0. 37	0. 16
July 29—11.40 a. m.	12.00 p. m.	12. 20	10. 95	0. 89
July 29-30—11.40 a. m.	5.20 a. m.	17. 40	11. 32	0. 64

The following table gives the precipitation at several neighboring rainfall stations from July 23 to 31, inclusive:

Precipitation at stations near Bridgeport, Conn., July 23-31, 1905.

Station.	July—								
	23.	24.	25.	26.	27.	28.	29.	30.	31.
Cream Hill[a]	0.07	0.53	....	Tr.	....	....	0.86	2.39	0.23
Hartford	0.02	0.83	Tr.	....	....	....	0.04	0.72	Tr.
Hawleyville	0.05	0.77	....	....	....	....	0.16	2.22	0.35
New Haven	0.43	0.37	....	Tr.	....	....	0.90	0.41	0.01
Norwalk	0.26	1.03	....	....	....	....	1.43	0.31	0.09
Torrington	0.02	Tr.	1.16	....	....	Tr.	....	0.97	0.40
Waterbury	0.06	0.83	....	Tr.	....	....	1.77	....	0.04
Beaver Dam[b]	0.31	0.39	....	....	....	....	9.86	0.61	......
Bridgeport	0.39	0.63	....	....	....	....	10.95	0.55	......
Easton	....	0.62	....	....	....	....	7.91	0.18	......
Bunnell Pond	0.36	0.48	....	....	....	....	[c]8.00	[c]2.00	......

[a] The first six stations are United States Weather Bureau stations. Data furnished by William Jennings, United States Weather Bureau observer.
[b] The last four stations are stations of the Bridgeport Hydraulic Company. Data furnished by S. P. Senior, superintendent Bridgeport Hydraulic Company.
[c] Approximate.

The table shows that the storm was very intense over a comparatively small area, the greatest rainfall occurring in the Pequonnock Valley in the vicinity of Bridgeport.

DISCHARGE.

The run-off from a rainfall of 8 to 11 inches in seventeen hours on this quick-spilling basin soon overtaxed the natural capacity of this rather small, crooked channel and overflow occurred, carrying débris that more or less reduced the channel capacity, especially the spillways of dams. Four dams failed, each one increasing the magnitude of the flood wave and adding débris to the already choked spillway of the dams below.

The rate of flow at Bunnell's dam, about 1½ miles above Bridgeport, at the time of its failure was computed to be 3,930 second-feet, or 157 second-feet per square mile. The length of the spillway was 52 feet, and the depth of water on the crest at the time of failure was 7.48 feet. Two smaller waste openings discharged 105 second-feet each.

This is a comparatively small run-off from such a large rainfall, and it is very likely that the maximum rate of flow occurred after the dam failed. By computing the run-off from rainfall and using a run-off factor of 0.5, the maximum rate of flow at this dam is found to be 248 second-feet per square mile. If 0.6 is used as the run-off factor the maximum rate is 297 second-feet per square mile.

DAMAGE DONE.

The Toucey dam, on a brook entering the Pequonnock from the west near Long Hill, gave way shortly before midnight of the 29th. It was 100 feet long, 10 feet high, built of rubble masonry laid in cement. Ward's milldam at Trumbull, on the Pequonnock, failed when the flood wave from Toucey dam struck it. It was 60 feet long, gave a head of 15 feet, and was built of rubble masonry laid in cement mortar. It was founded on a ledge and probably failed by sliding. At about 1 a. m. July 30, the dam at Bunnell Pond, 1½ miles above Bridgeport, failed. It was 800 feet long, 28 feet high, built of earth with a masonry spillway. It had a puddle core, a top width of 30 feet, upper slope 1.5 to 1, lower slope 1 to 1. In addition to a spillway 52 feet long, there were two openings 3 feet 10½ inches by 1 foot 8½ inches and a circular opening 4 feet in diameter. Failure resulted from overflow, due in part to the blocking of spillway by débris. The fourth dam to fail was the Berkshire milldam. This was a masonry tidewater dam 140 feet long and 7 feet high. Its failure was probably due to undermining.

Several bridges were damaged, traffic was impeded, and ships at the mouth of the river were damaged. Fortunately the tide was at ebb stage when the flood wave reached the mouth of the river, otherwise the damage to shipping would have been greater.

FLOOD ON SIXMILE CREEK AND CAYUGA INLET, NEW YORK.

INTRODUCTION.

On June 21, 1905, occurred the largest and most destructive flood on Sixmile Creek and Cayuga Inlet in the recollection of the oldest inhabitant of Ithaca, N.Y. Up to that time

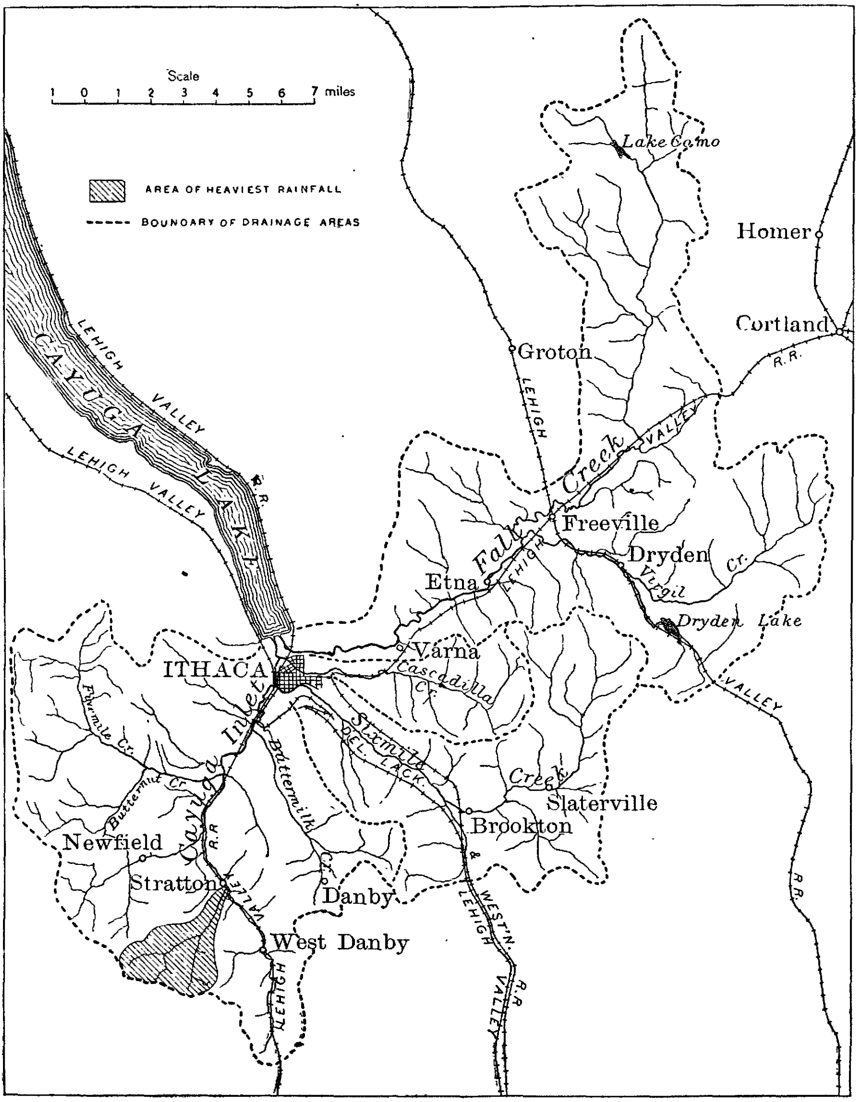


FIG. 1.—Drainage basin of Sixmile Creek and Cayuga Inlet, New York.

the flood of 1857 had been regarded as the largest on this stream, but the depth of overflow during the flood of June 21, 1905, was at least 1 foot greater than during the flood of 1857, as shown by well authenticated flood marks. The flood of 1905 was due to a cloud-burst, which fortunately did not cover a very large area. Had a storm of the intensity of this one covered the whole drainage area of these two streams the damage done at Ithaca and vicinity would have been very large.

The city of Ithaca is so situated that the effect of a storm in the drainage basin is almost the greatest possible. It is located on a low, flat area, with steep hills on three sides. The drainage area is characterized by steep slopes and nearly impervious soil, and is shaped somewhat like a fan, so that the three principal streams unite at about the same place in the city. Thus a very large volume of water, compared with the size of the drainage basin, is brought into the city very rapidly. The banks are eroded where the velocity of the water is high, the protection is poor, and gravel and small bowlders are deposited in a short time in other places where the velocity is low.

Fall Creek, Cayuga Inlet, Sixmile Creek, and Cascadilla Creek drain the area at the southern end of Cayuga Lake. Sixmile and Cascadilla creeks are really tributaries of Cayuga Inlet near its mouth (see fig. 1). Fall Creek, the largest of these four, drains an area of about 117 square miles. In about 22 miles it falls from an elevation of 1,306 feet at Lake Como to 381 feet at its mouth. The upper half of this basin is hilly, cultivated land; the lower half is more broken, with steep, pastured slopes. Cayuga Inlet drains an area of about 93 square miles, southwest of Ithaca. The watershed is rough, with steep pastured slopes, and some of the smaller tributaries extend to an elevation of about 1,900 feet above the sea level. Sixmile Creek drains an area of about 46 square miles lying directly east of Cayuga Inlet. Cascadilla Creek drains an area of about 16 square miles lying east of Sixmile Creek basin. Both of these basins have extremely steep slopes and their beds fall very rapidly until they reach the city limits.

Floods of considerable magnitude frequently occur on these streams. They are usually due to large rainfall over only a portion of one or another of the watersheds, and consequently all of the streams are not in destructive flood at the same time.

PREVIOUS FLOODS.

Flood of June 17, 1857 (*a*).—The flood of 1857 was due to a heavy rainfall over a comparatively small area, mainly on the watershed of Sixmile Creek. Almost no damage was done on Fall Creek and comparatively little on Cayuga Inlet.

There were two dams on Sixmile Creek at this time and both were destroyed. The fallen timbers of these structures formed a temporary dam in front of the stone arch bridge on Aurora street, and this obstruction caused the water to overflow its banks and run down State street and other streets parallel to it, flooding a part of the city which was not flooded during the flood of 1905. This stone arch bridge and other bridges on Sixmile Creek were destroyed by the flood. Marks left by this flood near State street show that at this place the flood of 1905 was about 14 inches higher than that of 1857.

Flood of December 14 and 15, 1901.—The flood of 1901, which is one of the three large floods that have occurred on Sixmile Creek, took place on the night of December 14 and the morning of December 15, as the result of heavy rain over a considerable portion of central New York and northern Pennsylvania. The United States Weather Bureau gage at Ithaca recorded 3.09 inches of rain from 8 a. m. on December 14 to 8 a. m. on December 15. All the streams entering the southern end of Cayuga Lake were in destructive flood. The maximum rate of flow of Sixmile Creek at Van Netta dam, about 2 miles above Ithaca, was computed by Prof. C. L. Crandall to be 6,070 second-feet.

FLOOD OF JUNE 21, 1905.

GENERAL FEATURES.

Copious rains had fallen for two or three days previous to the flood of June 21, 1905, and on the 21st heavy thunderstorms passed over the south-central part of the State, accompanied

[a] Data taken mainly from Ithaca Journal of January 24, 1857.

by very heavy local rain. The rainfall at six places in or near the drainage basins of Sixmile and Cascadilla creeks from 8 a. m. on the 20th to 8 a. m. on the 21st was as follows: Ithaca, 1.82; Elmira, 1.05; Binghamton, 1.00; Cortland, 1.38; Waverly, 0.53; Perry City, 1.26, and Kings Ferry, 1.73. The hourly rainfall at Ithaca from 4 a. m. to 4 p. m. on the 21st varied from 0.03 inch to 0.58 inch. These figures show only the local character of the storm. The rainfall indicated by them would not cause even a small flood on these streams. The intensity of the storm can be judged only by the maximum rate of flow and the damage done on each of the streams. This damage indicates that an exceedingly heavy rain fell on two comparatively small areas—on Sixmile Creek, in the vicinity of Brookton and Slaterville, and on Cayuga Inlet, in the vicinity of Stratton (see fig. 1).

FLOOD ON SIXMILE CREEK.

The heaviest rainfall occurred in the upper part of the watershed in the vicinity of Slaterville and Brookton. Several bridges here were destroyed and the banks of the streams were badly eroded. In some places a new channel was formed and the old channels were closed with bowlders and gravel. Some of the bottom land along the creek was badly damaged by the deposit of gravel upon it.

The maximum rate of flow is computed from measurements of cross section and slope between Aurora Street Bridge and Tioga Street Bridge. The channel here is approximately rectangular. From these data and a value of the coefficient of roughness "n" of 0.030, it is found that the mean velocity equals 15.8, and that the maximum rate of discharge was 8,980 second-feet, or 195.2 second-feet per square mile of drainage area.

The maximum rate of flow was also computed at the Sixmile Creek dam, 4 miles upstream from Ithaca, from the head on the dam, length of crest, and length of abutments. The discharge at this place was found to be 8,500 second-feet, which agrees closely with the computed flow after taking into account the difference of drainage area at the two places.

FLOOD ON CAYUGA INLET.

The flood on this creek began at about 10 a. m. and lasted for about five hours. Mr. G. H. Ellison, county commissioner, who lives on this stream and who has been over the greater part of the flooded area, states that the storm covered an area approximately circular in shape, the radius of the circle being about 3 miles. The storm was central over the small stream southwest of Stratton. Judged from the erosion of its channel the flood in this creek was exceedingly large. The highway and railroad bridges near the mouth of this stream were located at a bend in the stream, the width between abutments of the bridges being about 25 feet. A new channel, between 80 and 90 feet wide and 3 feet deep, was cut around these bridges, the old channel being filled with bowlders and gravel. The area of the watershed of this tributary is about 2.6 square miles. The extent of the erosion indicates that the rainfall on this basin must have been very great. The main stream also cut a channel around the bridge near the mouth of this gulch. The highway bridge, located about a half mile below the mouth of the gulch, was washed away, and the right bank of the stream was eroded for a distance of 50 feet back from the abutment.

AREA OVERFLOWED.

The stream began to overflow State street, Ithaca, about 3 p. m., reached its maximum stage about 5 p. m., and subsided below the street level about 1 a. m. of June 22. This overflow extended from a point about 1,200 feet east of the creek to a point 1,100 feet west of it, had a maximum depth of 3 feet, and a cross-section area of 4,120 square feet. The high-water line at this bridge was 8.9 feet above lake level on August 1, and about 9.5 feet above lake level just prior to the flood. The boundary of the area overflowed during this flood is shown on fig. 2. This area is probably somewhat less than that overflowed during the flood of 1901, for Fall Creek was not in flood and there was little overflow from Cascadilla Creek. But in some sections of the city the overflow reached places it had never reached before—at least not in thirty years.

DAMAGE.

The Lehigh Valley Railroad, which runs along Cayuga Inlet for several miles, was damaged to such an extent that trains could not pass over this part of the line for about a week. The first estimate of the damage done by this flood along this railroad between Ithaca and Sayre was $65,000. A later estimate, however, placed it at $100,000. The estimated cost of replacing bridges, protecting them from floods, and repairing the damage to roads in the town of Newfield was $8,000.

The dam at the Van Netta mill was swept away by the flood, leaving the city pumping station on Sixmile Creek without water for the city's supply, and without water power to work some of the pumps. The highway bridge over this dam was also destroyed.

The new 30-foot dam about 4 miles above Ithaca, on this stream, was uninjured; but the dam a few hundred feet below it, forming a water cushion for the water flowing over the 30-foot dam, was destroyed. The pipe line extending from the dam down the creek was considerably damaged by the washing out of the concrete supports.

The bridge at Clinton street was washed away; also the right abutment and the bank for a distance of about 55 feet back from the abutment (see fig. 3). The flood of 1901 eroded, to a large extent, the right bank of this stream from this bridge up to a point about 300 feet above the electric railway car barn. After the flood this bank was protected along a part of this distance by a concrete wall, along another part by piling and planks, and along a third part by piling and concrete. The concrete part was not injured by the flood of 1905 along the portion protected by piling, but the piles were washed away or badly damaged, and the part protected by piles and concrete was damaged to some extent. The water found its way back of the piling and eroded the bank in some places back to a distance of 55 feet. Fig. 3 shows a cross section of the channel at Clinton Street Bridge, taken August 1, 1905. The shaded area was washed away by the flood. The old channel is now filled with gravel to a depth of 2 to 3 feet.

Meadow Street Bridge was carried 900 feet downstream and left with a large mass of lumber in front of the Lehigh Valley Railway bridge. About a month after the flood this bridge was taken apart and replaced in its former location.

State Street Bridge was damaged to some extent and was closed to heavy traffic for about a month. A mass of drift collected in front of the bridge and prevented the water from passing freely through the natural channel.

SUGGESTED MEANS OF PREVENTING OR LESSENING OVERFLOW.

Overflow of the lowland in the vicinity of Ithaca results from two causes—(1) backwater from the lake, (2) overflow of one or more of the four creeks before mentioned. The elevation of the normal level of Cayuga Lake is 381 feet above sea. Its surface elevation fluctuates from about 5 feet above normal to 1¼ feet below normal.

A considerable area of land at the south end of the lake stands less than 5 feet above normal lake level, and is consequently subject to overflow from the lake, but it is not within the scope of this investigation to consider overflow from the lake alone. The elevation of the lake surface does, however, in a measure, affect the overflow of the creeks, because it controls the surface slope near the mouth of each. The sidewalk on State Street Bridge is about 9 feet above normal lake level, or 4 feet above high-water lake level. There would, therefore, be a surface slope of from 2 to 3 feet from the under surface of State Street Bridge to the lake, a distance of about 1 mile, when the lake level is at its maximum height.

The effects of floods on Sixmile Creek and Cayuga Inlet are intensified by the smallness of the channel and the obstructions in the streamway from State Street Bridge to a point below Buffalo Street Bridge. The average width of the channel along this portion of it is only 67

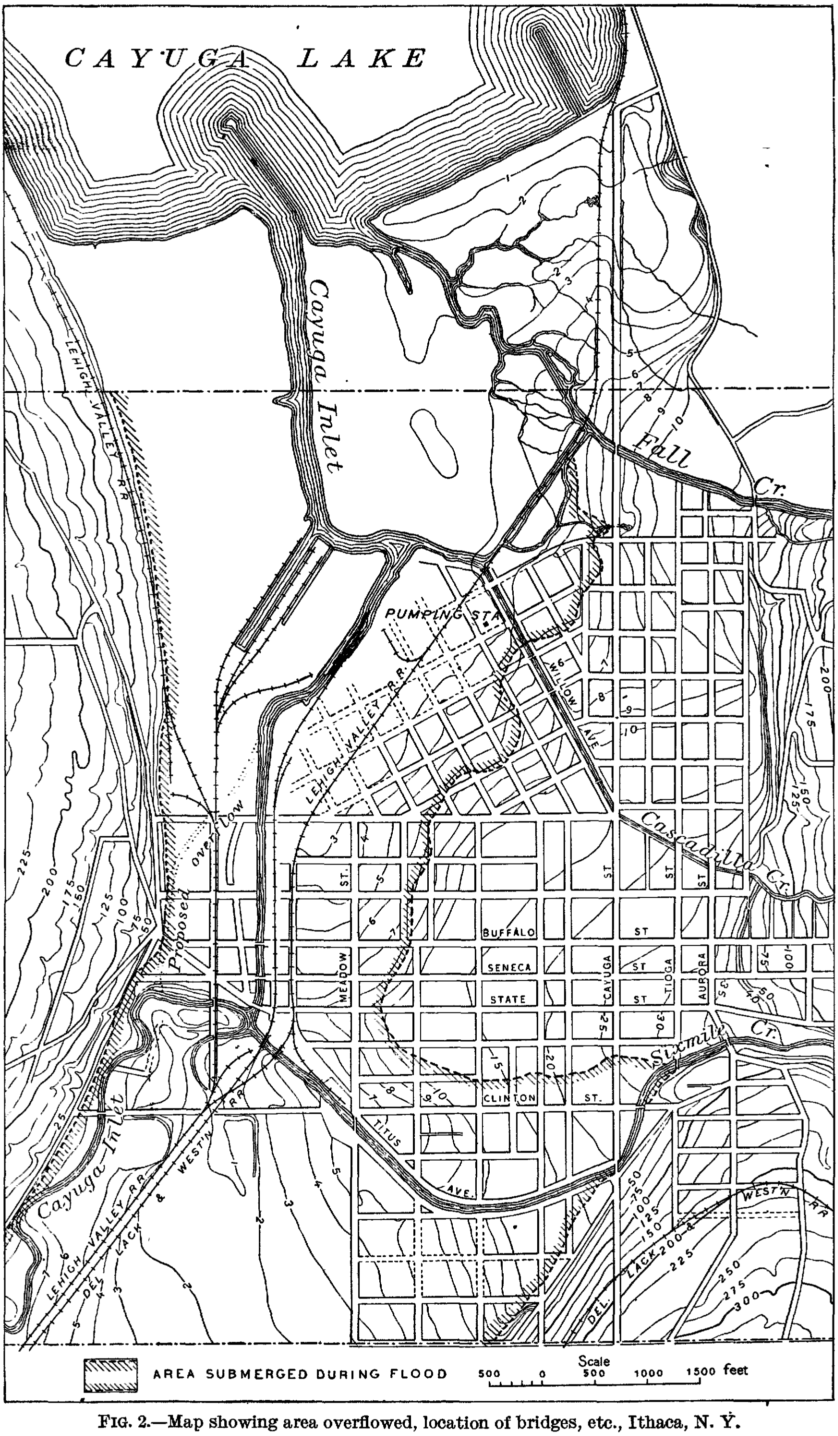


FIG. 2.—Map showing area overflowed, location of bridges, etc., Ithaca, N. Y.

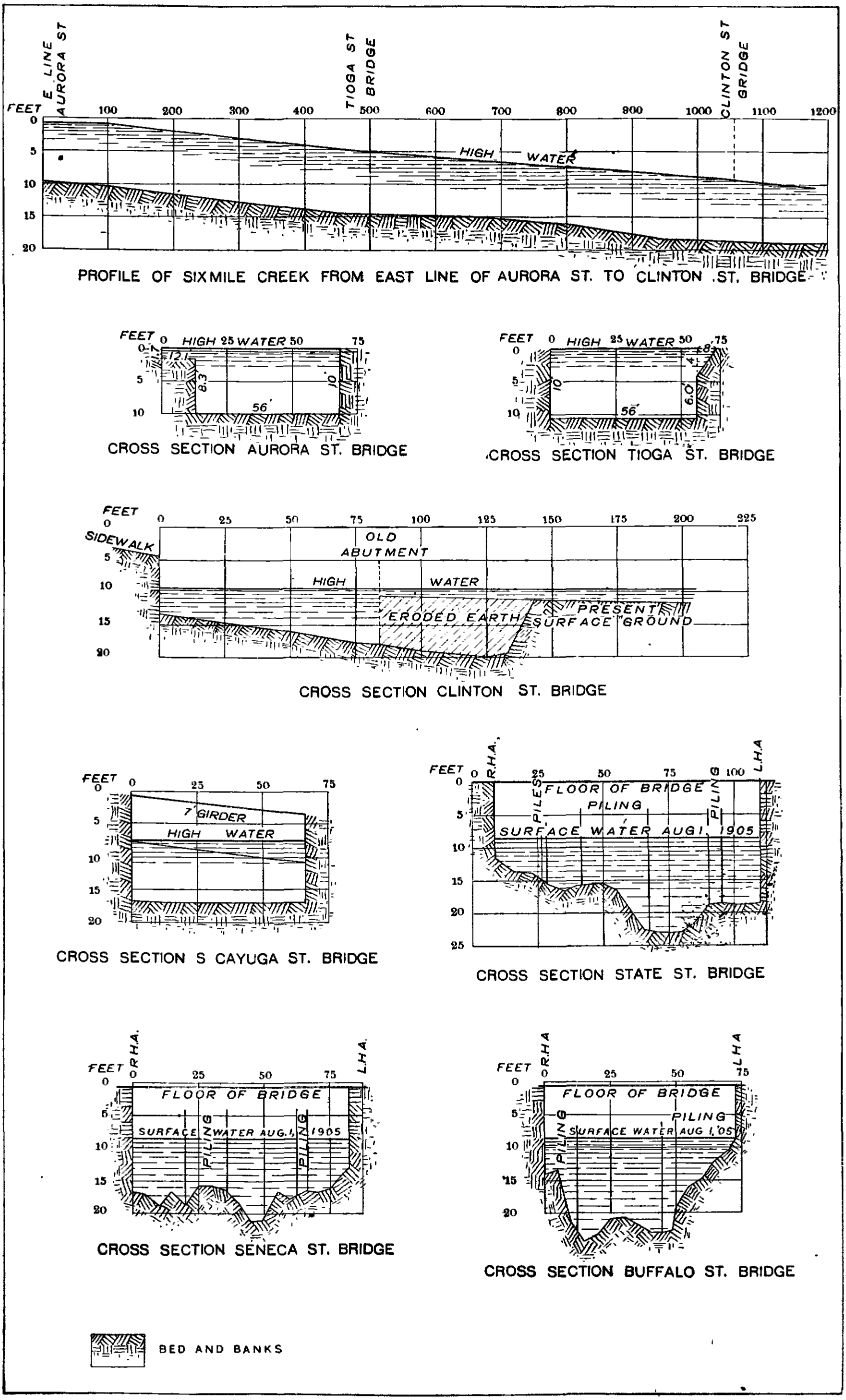


FIG. 3.—Flood profile and cross sections of Sixmile Creek.

feet. There are two or three groups of piles under each of these bridges, one being the group that supports the draw span of the bridge. The water cross section at each of these bridges up to the bridge floor, not making any allowance for the area of the piles in the channel, is as follows: State Street Bridge, 1,625 square feet; Seneca Street Bridge, 1,244 square feet; Buffalo Street Bridge, 1,210 square feet. These sections and the portion of each obstructed by piles are shown in fig. 3. With a surface slope of 2 to 3 feet, Cayuga Inlet, if unobstructed, would discharge 6,000 second-feet. The maximum flow being more than 15,000 second-feet, there remains a flow of 9,000 second-feet to be provided for, either by storage or by the construction of an overflow channel, if the overflow of State street is to be prevented during a flood of the magnitude of that of June 21, 1905.

It is not within the scope of this investigation to determine whether or not storage sufficient to control this amount of flow is obtainable. Judging, however, from the topography of the watershed, one would readily infer that such storage is possible; but the second solution of the problem, namely, the construction of an additional channel to carry off this surplus water, would be the most feasible. This solution has several times been recommended, but satisfactory data have not heretofore been available to determine the proper size of the channel. This channel would be about a mile long, and would be cut through low ground of little value and easy of excavation.

IMPROVEMENT OF CHANNEL OF SIXMILE CREEK.

The damage done by floods upon this creek, from a point about 800 feet above Aurora Street Bridge to Cayuga Street Bridge, would several times pay the expense of suitable bank protection. The flood of 1905 has taught a useful lesson as to the kind of protection, its height, and the proper width of the channel. The concrete work near Aurora Street Bridge was uninjured by this flood, but was not sufficiently high. The width of channel at this place is about 56 feet and the maximum depth of the water was about 10 feet. The bed was not injured by scour. Below Cayuga Street Bridge the grade of the stream bed decreases; hence the width of the channel should increase as State Street Bridge is approached. The height of the banks and the width of channel can easily be computed from the maximum rate of flow and the slope of the bed.

CONCLUSION.

Rainfall records are of little value in estimating the maximum flow of streams, especially the smaller ones. The maximum rates of flow are due to storms of short duration and great intensity over small areas, and there is seldom a rain gage in the area of greatest precipitation. The maximum rate of flow of Sixmile Creek at Ithaca, June 21, 1905, was about three times greater than its supposed maximum rate computed from rainfall records.

FLOOD ON THE UNADILLA AND CHENANGO RIVERS, NEW YORK.

By R. E. Horton and C. C. Covert.

INTRODUCTION.

Considerable damage was done in the valleys of the Unadilla and Chenango rivers, in Chenango, Otsego, and Madison counties, New York, on September 3 and 4, by a flood that caused the overflow of the smaller streams of these basins and the failure of culverts and reservoirs. The flood was the direct result of a short rain storm, of great intensity, that occurred after several days of rain, which had saturated the soil and filled the streams nearly bank full.

Unadilla River rises in the southern part of Herkimer County, flows southeastward for about 50 miles, and empties into the Susquehanna near Sydney. Its chief tributary is Wharton Creek, which enters it at New Berlin. The watershed is long and narrow, with numerous side grass-covered valleys and a moderate amount of woodland. The soil is clay and gravel, of considerable depth, underlain by rock. The smaller streams are precipitous, with beds of bowlders, shingle, and gravel, and as their headwaters are approached the beds become solid rock.

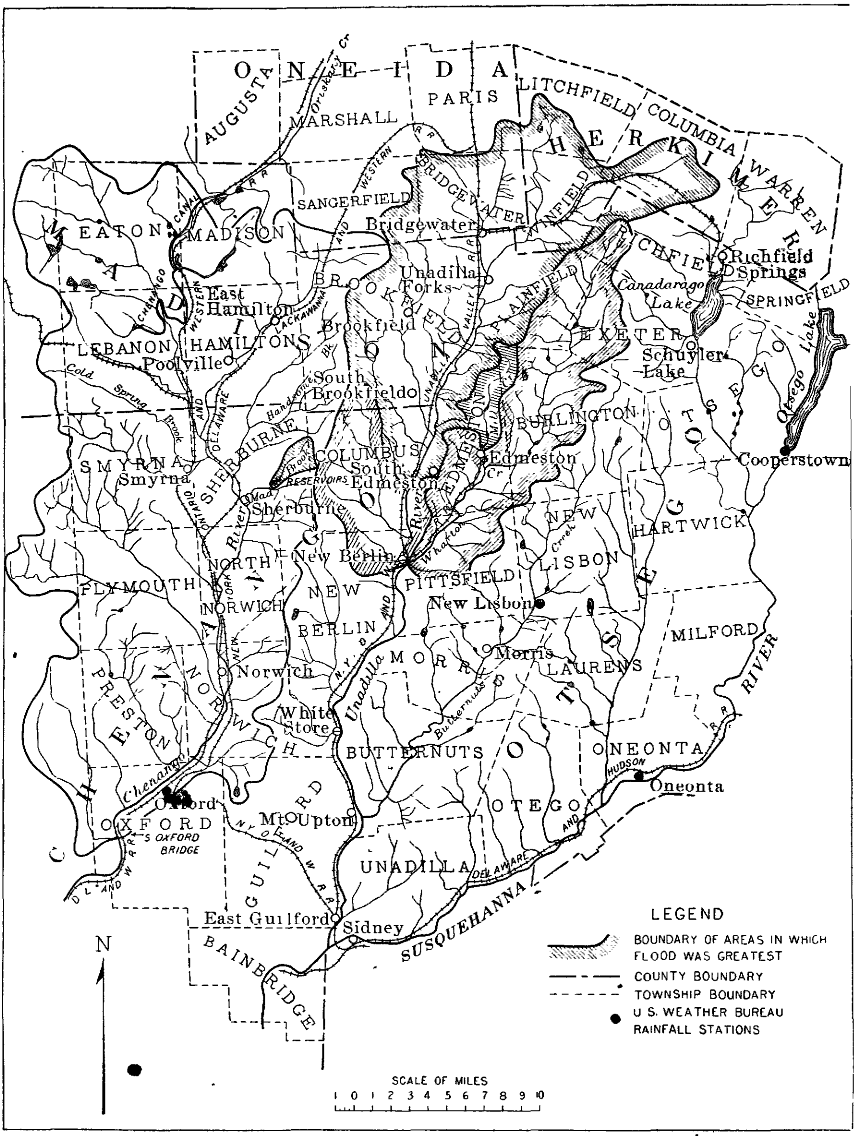


FIG. 4.—Map of drainage basins of Unadilla and Chenango rivers, New York.

Chenango River is located just west of the Unadilla, and its basin greatly resembles that of the Unadilla, being long and comparatively narrow, with numerous small side valleys. The side slopes are grass-covered and moderately steep.

The drainage areas of the streams on which most of the damage was done by this flood are approximately as follows:

	Square miles.
Mill Brook above Ackerman dam	9.4
Wharton Brook above mouth	95.0
Unadilla River above South Edmeston	172.0
Unadilla River, South Edmeston to electric light company's dam at New Berlin	32.0
Total, Unadilla River above dam, New Berlin	204.0
Susquehanna River above Sydney	914.0
Mad Brook above storage reservoir, near Sherburne	5.0
Chenango River above South Oxford Branch	423.0

PRECIPITATION.

The following table gives the depth of rainfall, in inches, at several stations of the United States Weather Bureau in the vicinity of these basins from August 29 to September 4, inclusive. Fig. 4 shows the watersheds of these streams and the location of some of these rainfall stations:

Precipitation in vicinity of the Chenango and Unadilla watersheds August 29 to September 4, 1905.

Station.	August—			September—				Total.
	29.	30.	31.	1.	2.	3.	4.	
Bouckville	0.31	2.13	0.00	0	0.22	0.80	1.36	4.82
Cooperstown	0.00	1.50	0.00	0	0.55	1.15	0.22	3.42
Cortland	0.30	1.25	0.28	0	0.11	(a)	1.53	3.47
De Ruyter	0.06	2.61	0.01	0	0.22	1.30	0.17	4.37
New Lisbon	0.31	1.70	0.02	0	0.42	0.12	1.92	4.49
Oneonta	(a)	1.84	0.00	0	Tr.	0.00	0.28	2.12
Oxford	0.15	1.41	0.40	0	0.42	0.50	0.55	3.43
Richmondville	0.00	0.96	0.00	0	0.49	0.03	0.24	1.72
South Kortright	0.18	1.43	0.28	0	Tr.	0.38	0.52	2.79
Little Falls	0.23	0.98	0.00	0	0.58	0.55	2.52	4.86
Graetenberg	0.31	0.33	0.80	......	....	1.20	0.87	3.51
Savage reservoir	0.38	0.37	0.91	......	....	1.21	0.87	3.74

[a] Amount included in next measurement

The Graefenberg and Savage reservoirs are located near Utica, a few miles north of the Chenango-Mohawk divide.

These rainfall data indicate only in a general way the precipitation for this period over these basins. None of the stations are located in the areas where the greatest damage was done. The rainfall at several of the stations was greater on August 30 than during the flood, this fact showing that the precipitation over the flooded basins was probably much greater than shown by these records. The measured rainfall and the damage done indicate a very heavy rain of short duration over a comparatively small area. The effect of this local storm was intensified by the heavy rains of the previous six days.

DISCHARGE.

The maximum discharge of some of the streams in the flooded area is given in the following table:

Maximum discharge of streams in Unadilla and Chenango basins.

Stream.	Locality.	Date.	Area (square miles).	Discharge.	
				Second-feet.	Second-feet per square mile.
Mill Brook	Ackerman dam, near Edmeston.	September 3, 4, 1905.	9.4	2,300.0	241.0
Unadilla River	New Berlin Electric Light and Power Company's dam.	September 3, 4, 1905.	204.0	8,200.0	40.0
Mad Brook	Upper storage reservoir, Sherburne.	September 3, 4, 1905.	5.0	1,300.0	262.0
Starch Factory Creek.	Near Utica	September 3, 4, 1905.	3.4	712.0	209.0
Do	do	June 21, 1905	3.4	647.5	190.4
Do	do	March, 1903	3.4	367.0	108.0
Do	do	October 10, 1903	3.4	313.0	92.0
Do	do	March 25, 1904 [a]		372.0	109.4

[a] Melting snow.

The discharge of Starch Factory Creek at the gaging stations near Utica has been included for purposes of comparison. The records of flow at this station have been kept for three years, and the discharge obtained there is more accurate than that obtained at the other places mentioned in the table.

It is seen that the flood of September, 1905, on Starch Factory Creek was somewhat larger than that of June 21, 1905, and considerably larger than those of 1903 and 1904. As far as known, the storm that caused the flood of June, 1905, did little damage in the Unadilla and Chenango basins. The duration of the September flood of 1905 was from twelve to fifteen hours, and was somewhat longer on the Chenango than on the Unadilla River.

In the Chenango basin the magnitude of the flood, as well as the damage done, was much less than in the Unadilla basin. This difference was due in part to the interception of a part of the flood water for storage in the State reservoirs in the upper Chenango basin. These reservoirs, which are located in the vicinity of Hamilton, had been drawn down during the months preceding the flood to supply the Erie Canal. As a result the run-off from the area tributary to them—comprising 30 square miles, mostly hillside land—was intercepted and stored in the reservoirs, and the damage that would have resulted from the passage of this volume of water down the streams was thus prevented.

The maximum discharge of Chenango River at Binghamton, near its mouth, during this flood was 17,400 second-feet at 5 p. m. September 5. On March 2, 1902, the discharge of this stream at this place was 35,950 second-feet—that is, twice as great as during the flood of 1905. The maximum discharge of the Susquehanna at Binghamton during the flood was 29,240 second-feet at 5 p. m. September 4. On March 2, 1902, the maximum discharge here was 60,400 second-feet—that is, more than twice that measured during the flood of September, 1905. The March flood on the Susquehanna was not only twice as large, but was of much longer duration, and was due to the melting of ice and snow, as well as to rain.

DAMAGE.

The greatest damage caused by this storm occurred in the village of Edmeston, at New Berlin, and elsewhere along Wharton Creek and Unadilla River. The failure of the Sherburne Waterworks reservoir, in the Chenango basin, resulted in severe damage below it.

The railroads passing through these basins suffered heavily and were out of service from one to two weeks. Three dams at Mill Creek above Edmeston failed, also one at Edmeston and one at New Berlin. These failures intensified the flood. The damage in the vicinity of the village of Edmeston is estimated at $25,000. The damage at New Berlin resulted from the choking of a stone arch culvert over a tributary of Paper Mill Brook, three-fourths of a mile above the village. This culvert became clogged with drift and the stream overflowed the arch and washed it away, flowing down Main street, scouring in some places to the depth of 8 or 10 feet, sweeping away the smaller buildings, filling cellars, and causing a loss of $10,000 to residences and business houses in the village. In the township of New Berlin 22 bridges were washed away, ranging in value from $25 to $1,400. The villages of Bridgewater, Brookfield, and North Brookfield also suffered heavily from this flood.

The village of Sherburne gets its water supply from two reservoirs on Mad Brook, about 2 miles northeast of the village. The upper or storage reservoir, having a capacity of 10,000,000 gallons, was formed by an earth embankment 300 feet long, 35 feet high, and 10 feet thick on the top. There is a spillway 35 feet wide, 6 feet deep, with a slope of 1 in 350 at one end. During this flood the water in this reservoir rose to the height of 1 foot above the top of this embankment and scoured out a U-shaped section 150 feet in width at the top to the base of the embankment. The lower reservoir also was damaged to some extent.

Nearly every bridge in the towns of Exeter, Columbus, Sherburne, Pittsfield, Edmeston, and New Berlin were either washed away or badly damaged.

FLOOD ON ALLEGHENY RIVER, PENNSYLVANIA-NEW YORK.

INTRODUCTION.

The spring freshet of March 18–31 on the Allegheny and upper Ohio rivers was not the largest or most destructive that has occurred on these streams, but nevertheless approached closely the maximum recorded stage at some places along the Allegheny and caused much loss of property and inconvenience.

The highest stage at Pittsburg was 29 feet, which is 4.2 feet below the height reached during the great flood of 1884, but only 1 foot below that of the flood of 1904, when about $1,000,000 worth of property was destroyed in western Pennsylvania and eastern Ohio. The highest stage of the Monongahela at Lock No. 4, Pennsylvania, was 27.2 feet, which is 15 feet below maximum recorded stage. The failure of this stream to yield the rate of flow expected resulted in a stage 2 feet less than was predicted.

The flood was the result of rapid melting of snow on five days (March 16–20), and a rainfall of 0.75 inch on the 19th and 0.50 inch on the 20th. The ice gorges held back large volumes of water and augmented the maximum rate of flow.

Allegheny River rises in northern Pennsylvania, at an altitude of about 2,500 feet. It flows northwestward into New York, then southwestward through Pennsylvania, and joins the Monongahela at Pittsburg, Pa., to form the Ohio. Its length, measured along the stream, is 325 miles, and the area drained by it comprises 11,100 square miles. From its mouth to Olean, N. Y., a distance of 255 miles, the slope is gradual and slightly less than 3 feet per mile. From Olean to Salamanca, N. Y., a distance of 23 miles, the fall is 1.85 feet per mile.

The greater part of the watershed is mountainous or hilly, with steep, nearly impervious slopes and no surface storage; hence the run-off is rapid. The rapid melting of snow, which in places in the upper part of the watershed has a depth of 3 feet, and the formation of ice gorges cause great floods, especially in the sluggish stretches of the stream. One of the largest of these ice freshets occurred January, 1877.[a]

---

[a] Report of Chief of Engineers U. S. Army for 1880, pt. 2, p. 1769.

PRECIPITATION.

There are no authentic records of the depth of snow accumulated during the winter of 1904–5 or its water equivalent. The following record of water equivalent of snow at three places in New York State [a] will show in a general way the probable water equivalent of the snow in the upper part of this basin:

Water equivalent of snow on ground at Hancock and near Utica, N. Y., during February and March, 1905.

Date.	Hancock.	Utica.	Graefenberg reservoir, near Utica.
	Inches.	*Inches.*	*Inches.*
February 6	1.85	2.39	5.06
February 13		3.27	5.97
February 14	2.93		
February 20	3.49		6.25
February 21		3.27	
February 27	2.45		7.30
February 28		3.18	
March 6	2.40	2.89	6.66
March 13	1.30		6.03
March 20	1.35		4.88
March 27			3.37

During the five days comprising March 16–20 the temperature in this basin was as follows:

Temperatures in Allegheny River basin March 16–20, 1905.

Date.	Maximum.	Minimum.	Date.	Maximum.	Minimum.
	°F.	°F.		°F.	°F.
March 16	55	21	March 19	59	42
March 17	62	31	March 20	48	32
March 18	67	36			

These high temperatures were accompanied by considerable rain, especially on March 19 and 20, averaging for 16 stations in this basin 0.75 inch on the 19th and 0.50 inch on the 20th. As a result of this rain and melting snow the tributaries rose rapidly during the 19th and 20th and reached a maximum stage generally on March 20.

[a] Data furnished by R. E. Horton, district hydrographer.

THE FLOOD.

The gage heights at several points are shown in the following table:

Gage heights in feet, in Allegheny River basin, March 18–31, 1905.

Date.	Freeport.[a]	Oil City.[a]	Redhouse, N. Y.[b]	Monongahela River at Lock No. 4, Pa.[a]	Redbank Creek, Brookville, Pa.[a]	Clarion River, Clarion, Pa.[a]	Conemaugh River, Johnstown, Pa.[a]
March 18	10.0	4.2	6.5	9.6	1.4	7.4	6.4
March 19	16.8	15.5	11.4	9.9	5.0	10.8	7.6
March 20	[c]31.2	17.6	11.6	14.4	5.8	16.0	8.8
March 21	28.5	14.9	11.7	16.5	4.0	11.0	9.0
March 22	26.3	14.1	11.1	27.2	3.8	9.6	7.0
March 23	21.5	12.3	9.9	20.5	2.8	7.7	5.4
March 24	18.0	11.1	9.6	13.3	2.0	6.8	4.5
March 25	17.4	11.0	9.6	12.9			
March 26	16.8	10.8	9.7	13.3			
March 27	17.5	10.4	9.9	13.2			
March 28	18.0	10.3	9.8	12.3			
March 29	15.0	9.4	9.3	10.9			
March 30	13.0	8.6	8.8	10.0			
March 31	11.8	7.9	8.2	9.2			

[a] U. S. Weather Bureau Station.
[b] This gaging station is described in Water-Sup. and Irr. Paper 128, p. 45.
[c] Maximum, 32 feet.

The Freeport station is just below the mouth of Kiskiminitas River and is 28 miles above Pittsburg. The highest stage at Freeport was 32 feet—that is, 31.3 feet above low water—on March 20. The highest recorded stage was 32.7 feet on February 18, 1891. The maximum of 1905 lacked only 0.7 foot of being as high as the highest since 1890 at this place. The following table gives the maximum stage of the river at Freeport each year from 1890 to 1905:

Flood stages of Allegheny River at Freeport, Pa., 1890–1905.

Year.	Date.	Gage height.[a]	Year.	Date.	Gage height.[a]	Year.	Date.	Gage height.[a]
		Feet.			Feet.			Feet.
1890	January 16	16.0	1895	April 10	20.6	1901	April 21	23.0
1890	April 10	20.0	1896	March 31	20.2	1902	March 1	28.8
1890	May 24	22.1	1897	March 6	19.5	1903	February 5	23.5
1891	February 18	32.7	1898	March 24	25.3	1904	January 23	30.1
1892	March 28	17.5	1899	March 7	17.0	1904	March 4	27.9
1893	May 18	22.8	1900	January 22	17.5	1905	March 20	[b]31.2
1894	May 22	24.5						

[a] U S Weather Bureau gage heights.
[b] Maximum, 32 feet.

The greatest stage at Oil City, 123 miles above Pittsburg, was 17.6 feet on the 20th. On March 17, 1865, the stage at this place was 21 feet—that is, 3.4 feet higher than during this flood.

The greatest stage at Redhouse, about 15 miles above the New York-Pennsylvania line, was 11.7 feet on March 21. This is less than 9 feet above ordinary low stage. There was no overflow worthy of mention here or above this station.

The maximum stage during this freshet at Lock No. 4, on the Monongahela, about 40 miles above its mouth, was 27.2 feet on the 22d. The rate of flow was 94,000 second-feet. The highest recorded stage is 42 and the highest discharge is 207,000 second-feet. The volume contributed to this flood by this stream was comparatively small. This small run-off is partly due to a freshet of greater magnitude, which occurred from the 8th to the 14th, and which removed most of the snow from the watershed.

The details of river stage at Kittanning, Pa., 45 miles above Pittsburg, are shown below. The ice jam at Ford City, about 3 miles below, broke at about 10.30 a. m. on March 18.

Gage heights and discharge of Allegheny River at Kittanning, Pa., March 18–24, 1905.

Date.	Hour.	Gage height.	Dis-charge.	Date.	Hour.	Gage height.	Dis-charge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
March 18	10.30 a. m.	16.40	82,900	March 20	2.00 p. m.	28.75	240,200
March 18	11.30 a. m.	15.30	73,000	March 20	2.30 p. m.	28.70	239,400
March 18	3.30 p. m.	12.10	47,830	March 20	2.45 p. m.	28.70	239,400
March 18	4.00 p. m.	11.95	46,810	March 20	4.00 p. m.	28.60	237,900
March 18	4.30 p. m.	11.85	46,140	March 20	4.30 p. m.	28.50	236,400
March 19	11.00 a. m.	16.50	83,840	March 21	7.15 a. m.	25.50	192,800
March 19	12.30 p. m.	17.60	94,560	March 21	8.15 a. m.	25.30	190,000
March 19	2.00 p. m.	18.40	102,800	March 21	10.30 a. m.	24.80	182,900
March 19	2.30 p. m.	18.70	105,900	March 21	11.15 a. m.	24.70	181,500
March 19	3.15 p. m.	19.50	114,700	March 21	11.50 a. m.	24.60	180,100
March 19	4.15 p. m.	20.45	125,600	March 21	2.10 p. m.	24.25	175,200
March 19	4.45 p. m.	20.90	131,000	March 21	3.10 p. m.	24.10	173,100
March 19	5.40 p. m.	22.15	145,640	March 22	7.45 a. m.	22.35	149,200
March 19	5.55 p. m.	22.50	151,200	March 22	9.00 a. m.	22.20	147,300
March 19	6.15 p. m.	22.90	156,600	March 22	11.00 a. m.	22.00	144,700
March 19	6.35 p. m.	23.25	161,300	March 22	12.45 p. m.	21.75	141,500
March 20	7.15 a. m.	28.40	235,000	March 22	2.00 p. m.	21.60	139,600
March 20	8.15 a. m.	28.55	237,200	March 23	6.30 a. m.	19.25	111,900
March 20	11.15 a. m.	28.75	240,200	March 24	6.00 a. m.	16.50	83,840
March 20	12.30 p. m.	28.80	240,900	March 25	7.00 a. m.	16.05	76,680

The highest stage at Kittanning was 28.8 feet on the gage, or 26.5 feet above ordinary low water. It lacked 6 to 8 inches of the height reached by the flood of 1865, and probably lacked 8 inches or more of reaching the height of the flood of 1832. The rise was very rapid, about 5 feet the first day and 10 feet the second. The maximum daily rate of discharge was 231,990 second-feet, or 26.7 second-feet per square mile.

FLOOD ON OHIO RIVER.

The gaging station on this stream is at Wheeling, W. Va., 90 miles below Pittsburg, Pa. The drainage above it, including the Allegheny and Monongahela basins, is 23,800 square miles. Beaver River, which joins the Ohio from the north 25 miles below Pittsburg, is the only comparatively large stream entering between Pittsburg and Wheeling. Its drainage area comprises 3,030 square miles. The first comparatively large stream that joins the Ohio below Wheeling is the Muskingum River. It enters from the north at Marietta, 81 miles below Wheeling, and has a drainage of 7,740 square miles.

The magnitude and duration of the flood of March, 1905, can be seen from the data in the following table:

Stages of Ohio River and tributaries during flood of March, 1905.

Date.	Ohio River at Wheeling, W. Va.		Ohio River at Davis Island dam.[a]	Ohio River at Marietta.[b]	Ohio River at Cincinnati.[c]	Beaver River at Elwood Junction, Pa.[d]	Muskingum at Zanesville.[e]	Kanawha at Charleston, W. Va.[f]
	Gage height.	Discharge.	Gage height.	Gage height.	Gage height.	Gage height.	Gage height.	Gage height.
	Feet.	*Sec.-feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
March 18	10.9	54,340	9.5	10.75				
March 19	14.9	85,700	14.1	12.6	25.3	4.3	11.1	6.5
March 20	28.2	205,200	23.2	20.7	22.3	9.6	13.7	7.0
March 21	39.7	329,200	26.1	32.8	21.2	9.0	15.6	8.0
March 22	[g] 42.3	359,600	27.1	39.1	28.8	9.0	17.3	9.8
March 23	41.8	353,700	23.1	40.4	37.1	6.0	16.9	10.8
March 24	34.0	265,600	17.2	38.8	42.2	5.0	15.9	8.5
March 25	26.2	185,500	15.0	33.7	45.0	4.0	14.5	7.3
March 26	23.2	157,000	15.1	27.2	46.8	4.0	13.0	7.2
March 27	22.6	151,500	14.5	23.6	47.0	4.0	11.8	7.0
March 28	21.2	138,900	13.8	21.3	45.4	3.9	10.9	6.4
March 29	19.9	127,500	12.8	19.8	42.2	3.9	10.2	6.0
March 30	17.9	110,400	11.5	18.1	38.7	3.8	9.8	5.5
March 31	15.9	93,790	10.6	16.4	35.2	3.8	9.5	5.3
April 1	14.0	78,500			31.3			
April 2	12.4	65,920			28.4			
April 3	10.9	54,340			26.0			

[a] Highest stage 32.3 feet February 7, 1884.
[b] Highest stage 46.5 feet February 7, 1884.
[c] Highest stage 71.1 feet February 14, 1884.
[d] Highest stage 18 feet May 18, 1893.
[e] Highest stage 35.9 feet March 24, 1898.
[f] Highest stage 46.9 feet September 29, 1861.
[g] Maximum stage 42.7 feet 8 p. m.

The Ohio at Davis Island dam, 5 miles below Pittsburg, reached on March 22 a maximum stage of 27.1 feet, which is 5.2 feet less than the maximum reached during the great flood of February, 1884. On the same date it reached a maximum stage of 42.3 feet and a rate of flow of 359,600 second-feet at Wheeling. On February 7, 1884, the river reached a stage of 53.1 feet at Wheeling and a maximum rate of flow of 494,200 second-feet.

At Cincinnati, Ohio, a maximum stage of 47 feet was reached on the 27th, which is 24.1 feet below the height reached by the flood of 1884. The maximum stage of Beaver River at Elwood Junction, Pa., was 8.4 feet below the highest recorded stage.

During this flood the Muskingum at Zanesville was 18.6 feet below, and the Kanawha at Charleston was 36.1 feet below the maximum recorded stage. It is evident, therefore, that this flood came mainly from the Allegheny River and that its magnitude, compared with other great floods, decreased as it traveled downstream.

The following table gives the date of occurrence and daily rate of flow of the Ohio at Wheeling during the large floods from 1884 to 1905:

Flood flow of Ohio River at Wheeling, W. Va., 1884–1905.

[Danger line, 36 feet; drainage area, 23,800 square miles.]

Year.	Date.	Gage height.	Discharge.	Year.	Date.	Gage height.	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1884	February 5	23.0	155,100	1893	May 19	31.5	239,000
	February 6	38.0	309,800		May 20	29.5	218,400
	February 7	53.1	494,200	1895	January 8	28.8	211,300
	February 8	46.5	410,400		January 9	36.0	287,500
	February 9	41.3	347,800		January 10	30.7	230,700
	February 10	36.0	287,500		January 11	26.0	183,500
	February 11	32.0	244,300	1897	February 23	19.5	124,000
1885	January 17	26.0	183,500		February 24	35.3	279,800
	January 18	32.8	252,800		February 25	37.0	298,600
	January 19	27.8	201,200		February 26	27.0	193,300
1886	April 1	23.8	162,600	1898	March 22	25.6	179,760
	April 2	31.0	233,800		March 23	35.4	280,900
	April 3	28.0	203,200		March 24	*a* 43.9	378,700
	April 6	22.0	146,000		March 25	42.9	366,700
	April 7	31.3	237,000		March 26	37.0	298,600
	April 8	32.0	244,300		March 27	29.9	222,500
	April 9	27.0	193,300	1900	February 10	25.0	173,900
1887	February 8	25.0	173,900	1901	April 20	23.8	162,600
	February 9	30.9	232,800		April 21	37.0	298,600
	February 10	30.6	229,700		April 22	*a* 41.3	347,800
	February 11	29.4	217,400		April 23	37.0	298,600
	February 12	29.8	221,500		April 24	32.2	246,400
	February 13	33.8	263,500		December 17	33.9	254,900
	February 14	29.8	221,500	1902	March 1	28.8	211,300
1888	August 22	16.3	97,060		March 2	42.0	356,000
	August 23	32.2	246,400		March 3	42.0	356,000
	August 24	25.6	179,700		March 4	37.9	308,700
1890	March 23	26.9	192,300		March 5	30.0	223,500
	March 24	32.5	249,600		April 11	32.9	253,800
	March 25	30.4	227,600	1903	March 1	28.6	209,300
	March 26	21.8	144,200		March 2	39.7	329,200
1891	January 3	29.4	217,400		March 3	37.3	308,000
	January 4	32.9	253,800	1904	January 23	34.2	267,800
	January 5	26.8	191,300		January 24	43.9	378,700
	February 17	25.0	173,900		January 25	41.0	344,300
	February 18	40.0	332,700		January 26	31.5	239,000
	February 19	44.6	387,200		March 8	28.4	207,200
	February 20	40.5	338,500		March 9	36.3	290,800
	February 21	34.5	271,000		March 10	29.3	216,400
	February 22	29.8	221,500		March 11	22.3	148,800
1893	February 7	20.9	136,200		April 3	33.9	264,600
	February 8	31.6	240,100	1905	March 11	27.7	200,200
	February 9	32.0	244,300		March 21	39.7	329,200
	February 10	28.0	203,200		March 22	42.3	359,600
	February 11	28.9	212,300		March 23	41.8	353,700
	February 12	32.1	245,400		March 24	34.0	265,600
	February 13	27.0	193,300		March 25	26.2	185,500
	May 18	23.8	162,600				

a Probable mean for day. Maximum, 54 feet.

The largest flood at this place during the twenty-two years covered by the table occurred in February, 1884. On February 7 the maximum stage was 54 feet, the mean stage for the day about 53.1 feet, and the rate of flow 494,200 second-feet, or 20.8 feet per square mile. During this flood the river rose 10.8 feet higher, had a rate of flow 134,600 second-feet greater, and was of two days' longer duration than during the freshet of March, 1905. Second in rate of flow was the flood of February, 1891, when the stage at 8 a. m. on the 19th was 44.6 feet, and the greatest daily rate of flow was 387,200 second-feet. Third in magnitude was the flood of March, 1898; fourth, that of January, 1904; and fifth, that of March, 1905.

All the large floods occurred during the spring or winter months and were due to rapid melting of snow. The largest summer flood was in August, 1888. The maximum stage was 32.2 feet and the rate of flow was 246,400 second-feet. That is about 0.6 the rate of the maximum spring flood.

The river stood above the danger line for four days, from the 6th to the 9th, inclusive, during the flood of 1884, and for three days, March 21 to 23, during the flood of 1905.

The total flow for the four days comprising February 6–9, 1884, less the total flow for these days at the danger line (36 feet) is about 802,100 acre-feet. The total flow for the three days comprising March 21–23, 1905, when this stream was above the danger line, less the total flow for the same period at the danger line, is about 357,000 acre-feet. These figures show approximately the storage necessary to prevent this stream from passing the danger line at this place during floods.

The following table gives the highest stage each year, from 1860 to 1905, at Cincinnati, Ohio, for the years that the river rose above 50 feet on the gage:

Flood stages of Ohio River at Cincinnati, Ohio.

[Danger line, 50 feet of gage; lowest stage, 1.9, September 17-19, 1881.]

Year.	Date.	Stage.	Year.	Date.	Stage.	Year.	Date.	Stage.
		Feet.			*Feet.*			*Feet.*
1832	February 18	64.3	1880	February 17	53.2	1893	February 20	54.9
1847	December 17	63.6	1821	February 16	50.6	1897	February 26	61.2
1862	January 24	57.3	1882	February 21	58.6	1898	March 29	61.4
1865	March 7	56.3	1883	February 15	66.3	1899	March 8	57.2
1867	March 14	55.8	1884	February 14	71.1	1901	April 27	59.7
1870	January 19	55.3	1886	April 9	55.8	1902	March 5	50.9
1875	August 6	55.3	1887	February 5	56.3	1903	March 5	52.3
1876	January 29	51.8	1890	March 26	59.2	1905	March 13	48.3
1877	January 20	53.8	1891	February 25	57.3			

In these forty-six years the river at this place rose above 50 feet on the gage twenty-three times. It has been at stages from 0.7 to 0.8 of the maximum stage fifteen times; at stages from 0.8 to 0.9 of the maximum stage six times; and at stages from 0.9 to 1 of the maximum stage twice. In the seventy-four years, from 1832 to 1905 there have been three floods, reaching stages from 0.9 to 1 of the maximum stage.

FLOOD ON GRAND RIVER, MICHIGAN.

This flood, although not so large as that of March, 1904, was probably the largest summe flood recorded in the history of this stream. The following table, taken from the Unite States Monthly Weather Review for June, 1905, gives the precipitation for May and fo June 1 to June 6 at ten places in this drainage basin:

Precipitation in the basin of Grand River and its tributaries in May and June, 1905, in inches

Station.	River.	May.		June.						
		Amount.	Departure from normal.	1.	2.	3.	4.	5.	6.	Total
Jackson	Grand	6.12	+2.49	0.03	Tr.	0.24	0.78	2.15	0.79	3.9
Fitchburg	Cedar	6.37	+2.01	Tr.	0	0	0.28	0.40	3.15	3.8
Webberville	do	4.36		0	0	0	0.10	1.13	4.76	5.9
Agricultural College.	do	5.17	+1.95	0	0	0	0.11	0.45	5.47	6.0
Lansing	Grand	5.51	+1.98	0	0.01	0	0.18	0.28	4.92	5.3
St. Johns	Looking Glass	5.46	+2.37	0	0	0	0.04	2.18	3.90	6.1
Charlotte	Thornapple	3.79								3.5
Hastings	do	6.60	+3.22	0	0	0	0.68	0.50	3.60	4.7
Ionia	Grand									6.31
Grand Rapids	do	5.97	+2.49	0	0.20	0	0.36	1.20	3.56	5.3
Average		5.48	+2.36	Tr.	0.03	0.03	0.32	1.04	3.77	5.1

The rainfall for May exceeded the normal by 2.36 inches, so that the ground was full or nearly so at the time of this flood. From the 4th to 6th of June 5.13 inches of rain fell of this amount 75 per cent fell on the 6th.

The following table gives the daily gage height at Grand Rapids, Mich., from June 5 to June 17, and the daily gage height and corresponding discharge at this place during the flood of March, 1904:

Flood flow of Grand River at Grand Rapids, Mich., in 1904 and 1905.

[Drainage area, 4,900 square miles.]

Year.	Date.	Gage height.	Discharge.	Year.	Date.	Gage height.	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1904	March 20	9.20	16,700	1904	April 6	11.20	20,700
	March 21	9.30	17,000		April 7	10.50	18,800
	March 22	10.65	19,500		April 8	9.55	17,400
	March 23	11.45	21,400	1905	June 5	2.65	4,598
	March 24	15.60	30,300		June 6	10.6	18,820
	March 25	18.09	35,800		June 7	14.2	31,140
	March 26	19.05	37,800		June 8	18.1	47,990
	March 27	19.75	39,400		June 9	18.4	49,340
	March 28	19.36	38,500		June 10	17.7	46,100
	March 29	18.22	36,000		June 11	16.5	40,580
	March 30	16.77	32,900		June 12	15.3	35,425
	March 31	15.40	29,900		June 13	13.8	29,560
	April 1	14.45	27,800		June 14	12.5	24,850
	April 2	13.80	26,600		June 15	11.2	20,450
	April 3	13.80	26,600		June 16	9.9	16,770
	April 4	13.80	26,600		June 17	8.7	13,930
	April 5	12.80	24,500				

This stream rose rapidly on June 6, and reached a maximum of 18.4 feet on June 9. This flood, compared with that of March, 1904, was of shorter duration, more rapid rise and fall, and was 1.3 feet lower.

The lower part of the city of Grand Rapids was flooded. The damage done was small, compared with that of the flood of 1904, the difference in this respect being due largely to the timely warning of the height and progress of the flood given by the United States Weather Bureau.

The Muskegon and other streams in western Michigan were bank full, and in places overflowed lowlands and injured dams and bridges. Numerous washouts occurred on the railroads in western Michigan. The Pere Marquette reported thirty, some of them 200 feet long.

The streams in eastern Wisconsin, especially the Fond du Lac, were out of their banks as a result of the storm of June 6. A portion of Fond du Lac was flooded. Some washouts were reported on the Wisconsin Central and five on the Chicago and Northwestern.

The Sheboygan River was out of its banks at Sheboygan Falls, and caused damage in the low part of the town, and the Chippewa River overflowed at Eau Claire.

FLOOD IN EASTERN MISSOURI.

Heavy rains in Missouri and southern Illinois from September 15 to September 19 caused the Missouri River from Boonville to Hermann, Mo., to rise above the danger line, and some of the smaller streams of Missouri to be in destructive flood. The flood was remarkable for the time of year of its occurrence and the rapidity of its rise. The rain causing the flood occurred from the 15th to the 19th, but the larger part fell on the 17th. At Boonville, Mo., 12.98 inches fell from the 15th to the 19th. At Chester, Ill., 8.06 inches fell in 20.5 hours.

The streams rose very rapidly on the 17th. The following table gives the daily gage height of Meramec River at Meramec, the daily gage height and discharge of Meramec River at Eureka, Mo., and the gage height of the Gasconade River at Arlington, Mo., during this flood.

Flood flow of Meramec and Gasconade rivers during flood of September, 1905.

Date.	Meramec River, Meramec, Mo.	Meramec River, Eureka, Mo.		Gasconade River Arlington, Mo.
	Gage height.	Gage height.	Discharge.	Gage height.
	Feet.	*Feet.*	*Sec.-feet.*	*Feet.*
September 16	2.7	4.9	2,180	3.95
September 17	7.0	18.4	23,840	13.8
September 18	8.2	20.9	28,930	12.5
September 19	7.8	24.5	37,640	16.5
September 20	6.0	29.7	51,160	13.6
September 21	5.6	28.5	48,040	14.0
September 22	5.1	24.5	37,640	10.4
September 23	4.3	13.5	14,040	7.4
September 24	4.2	7.4	4,950	6.3
September 25	3.9	6.6	4,030	5.8
September 26	3.7	5.9	3,260	5.8

Gasconade River rises in the southeastern part of Missouri, flows in a general northeasterly direction, and empties into the Missouri River about 6 miles west of Hermann, Mo. It is a very crooked stream, with little fall. The basin is mainly hilly or rolling land, cultivated or grass covered. The area of this basin above the gaging station at Arlington is 2,725 square miles.

Meramec River rises in the eastern part of Missouri, flows in a general northeasterly direction, and empties into the Mississippi about 22 miles below St. Louis. The drainage basin is hilly or rolling, cultivated or grass-covered land, and comprises an area of 3,619 square miles. The area above the gaging station at Eureka is 3,497 square miles.

The maximum daily rate of the Meramec at Eureka during this flood was 51,160 second-feet, or about 14.63 second-feet per square mile.

During the flood of January, 1897, the Gasconade at Arlington reached a stage of 26.90 feet—that is, a stage nearly twice as high as that reached by it during the flood of 1905.

The following table shows the daily gage heights at four United States Weather Bureau stations—Boonville, Hermann, Grafton, and St. Louis—two on Missouri River, and two on Mississippi River. Boonville is 199 miles above the mouth of the Missouri; Hermann is 103 miles above the mouth; Grafton is on the Mississippi about 21 miles above the mouth of the Missouri, and St. Louis is about the same distance below.

Stages of Missouri River during flood of September, 1905.

Date.	Missouri River.		Mississippi River,	
	Boonville, Mo.[a]	Hermann, Mo.[b]	Grafton, Mo.[c]	St. Louis, Mo.[d]
	Feet.	*Feet.*	*Feet.*	*Feet.*
September 15	8.8	9.7	8.2	11.3
September 16	10.6	11.2	8.2	11.1
September 17	16.9	20.7	8.8	12.9
September 18	21.3	24.3	11.0	23.2
September 19	21.6	25.4	13.6	27.1
September 20	22.0	25.4	15.6	29.3
September 21	21.3	24.6	16.4	30.2
September 22	19.5	23.3	16.2	30.1
September 23	17.9	21.6	15.2	29.2

[a] Lowest recorded stage, −0.6 feet.
[b] Lowest recorded stage, 0.0 feet.
[c] Lowest recorded stage, −0.3 feet.
[d] Lowest recorded stage, −2.5 feet.

Some lowland along Missouri River was flooded and crops were damaged. Several of the smaller streams overflowed their banks, washed away some of the smaller bridges, and interfered with railway traffic for several days.

FLOODS IN SOUTH DAKOTA.

Freshets occurred on some of the streams of South Dakota in June, July, and August. The damage done was confined mainly to the Teton or Bad River in the vicinity of Fort Pierce. Heavy rain on July 2 and 3 caused this river to overflow its banks in a flood that swept away 17 houses and drowned 7 persons. There is no gaging station on this stream and the United States Weather Bureau gage at Pierce was carried away by the flood, so that records of river stage and rate of flow are not available for points in the eastern part of the State. There are several gaging stations in the western part of South Dakota, however, and data obtained there show magnitude of the floods in that part of the State.

The following table gives the gage heights during these freshets at gaging stations on the Cheyenne at Edgemont, the White at Interior, the Moreau at Bixby, and the Grand at Seim, and also the daily rate of flow at Edgemont:

Stages and flow of streams of South Dakota during freshets of June-August, 1905.

Date.	Cheyenne River at Edgemont.		White River at Interior.	Moreau River at Bixby.	Grand River at Seim.
	Gage height.[a]	Discharge.	Gage height.[b]	Gage height.[c]	Gage height.[d]
	Feet.	*Sec.-feet.*	*Feet.*	*Feet.*	*Feet.*
June 17	5.45	2,752	4.2	3.0	3.6
June 18	9.65	9,175	16.0	6.75	4.0
June 19	4.4	1,850	6.0	6.40	4.9
June 20				4.8	4.6
July 1	2.7	345	3.75	1.7	2.2
July 2	9.35	8,665	9.20	2.1	2.2
July 3	5.80	3,460	13.50	6.1	4.0
July 4			10.10	5.3	3.6
July 5			8.3		
July 19	2.1	75	2.35	3.3	2.6
July 20	7.7	6,280	4.05	3.1	2.8
July 21	5.9	3,595	2.95	2.15	2.9
July 28	6.0	3,730	4.25	2.25	2.1
July 29	10.7	10,960	9.50	1.9	2.6
July 30	9.7	9,260	7.00	1.8	2.4
July 31	6.0	3,730	6.30	1.75	2.1
August 5	2.95	562	3.35	1.5	2.1
August 6	7.95	6,842	3.05	1.5	2.0
Auguts 7	4.0	1,420	2.85	1.5	1.9
August 11	5.0	2,440	2.15	1.4	1.8
August 12	8.4	7,420	5.20	1.4	1.8
August 13	5.8	3,460	5.15	1.6	1.8

[a] Lowest reading, 1.4.
[b] Lowest reading, 1.6.
[c] Lowest reading, 1.0; discharge, 0.
[d] Lowest reading, 1.5.

These four streams drain the western half of South Dakota, flow in a general easterly direction, and empty into Missouri River. Seim is about 90 miles from the western boundary of the State, Bixby 72 miles, Edgemont 11 miles, and Interior 100 miles. The drainage area above Edgemont is 7,350 square miles; above Bixby, 1,600 square miles.

As the table shows, there were six freshets on the Cheyenne during the year—one in June, three in July, and two in August, the largest of the six being the fourth, during which the daily rate of discharge was 10,960 second-feet, or about 1.5 second-feet per square mile of drainage above station. These floods were of short duration, the high water lasting only a day.

During only three of these six flood periods did the flow of White River at Interior rise more than 5 feet above low water. The flood of June was the largest of the three on the White, the stage on the 18th being about 14.5 feet above low water.

During these flood periods the stage of the two streams in the northwestern part of the State—the Moreau and the Grand—was less than 6 feet above low-water.

FLOOD IN SOUTHEASTERN MINNESOTA.

Heavy rains in Minnesota from July 3 to July 6 caused the upper Mississippi to reach a stage of 14.8 feet at St. Paul, Minn., the highest since 1897. The flood of April, 1881, reached a stage of 19.7 feet.

The following table gives the daily gage heights of the Mississippi River at Sauk Rapids, Minn., during the freshet; also the gage height and rate of flow of two of the tributaries, the Minnesota, which enters from the west at St. Paul, and the Chippewa, which enters from the north 70 miles below St. Paul:

Flow of upper Mississippi River and tributaries during the freshet of July, 1905.

Date.	Chippewa River at Eau Claire, Wis.[a]		Minnesota River at Mankato, Minn.[b]		Mississippi River at Sauk Rapids.[c]
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.
	Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*
July 5	6.9	8,390	9.4	9,400	18.8
July 6	10.4	18,960	10.6	11,310	19.8
July 7	10.6	19,640	11.7	13,070	20.1
July 8	11.3	22,050	12.2	13,870	20.2
July 9	10.1	17,940	12.5	14,350	20.1
July 10	7.0	8,650	12.0	13,550	19.6
July 11	8.1	11,740	11.8	13,230	19.2
July 12	6.9	8,390	11.2	12,270	18.6

[a] Lowest stage during 1905, 4.1 feet; discharge, 2,010 second-feet.
[b] Lowest stage during 1905, 1.80 feet; discharge, 750 second-feet.
[c] Lowest stage during 1905, 11.25 feet.

The Chippewa at Eau Claire reached a stage of 19.6 feet and a discharge of 60,520 second-feet on June 8, 1905, and the Minnesota at Mankato, Minn., reached a stage of 19.6 feet on May 29, 1903, so that the greatest stage reached by the flood of July, 1905, on these streams was far below the highest recorded stages at these places.

FLOOD ON DEVILS CREEK, IOWA.

By E. C. Murphy and F. W. Hanna.

INTRODUCTION.

Lee County, in southeastern Iowa, and Hancock County, in western Illinois, which borders Lee County on the east, were visited by a very heavy rain storm during the night of June 9, 1905. As a result of this storm the streams in these counties rose to extraordinary heights, causing great damage to property. Railroads, highways, and bridges were severely injured, stream beds and banks were badly scoured in many places, and débris was transported and deposited throughout the creek valleys, destroying crops and damaging many acres of valuable land.

The data on which this report is based were obtained by investigating the conditions on the ground about one month after the flood, through facilities afforded by the courtesy of the engineers of the Santa Fe Railway. Owing to the lapse of time between the storm and the examination of its results the information obtained is necessarily incomplete.

The area affected by this storm is in the central Mississippi drainage basin. Devils Creek, the stream on which most of the damage was done, drains directly into the Mississippi a few miles below Fort Madison, Iowa. It rises in Marion and Cedar townships and flows in a general southeasterly direction for about 20 miles. Panther Creek, the largest vestern tributary of Devils Creek, rises in the southern part of Franklin township, flows n a general southeasterly direction about 8 miles, and joins the main stream about 3 miles bove its mouth. It drains an area of 14 square miles. The principal tributary of Devils Creek is Little Devils Creek, which enters it about 1 mile below the junction of Devils and Panther creeks. It is 7 miles long and drains an area of 19 square miles. The drainage area of Devils Creek and that of the lower part of each of these two tributaries consists of alluvial, sandy soil that erodes readily. The upper drainage area is covered with heavy

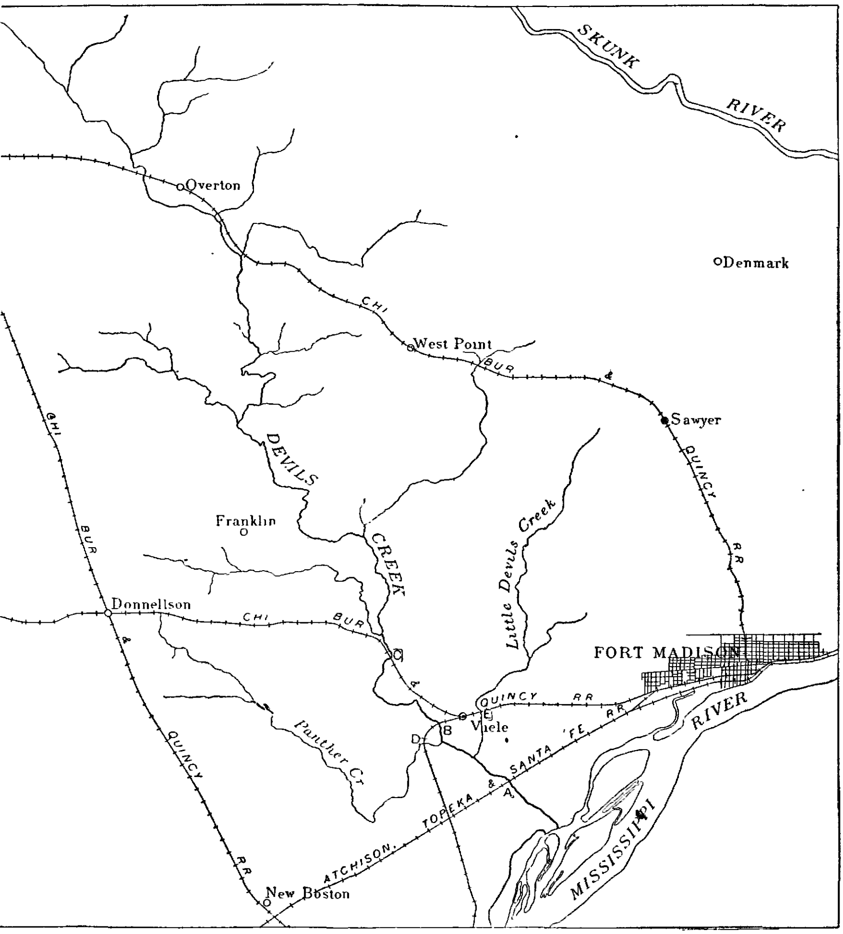


FIG. 5.—Map of drainage basin of Devils Creek, Iowa.

clay soil. There is little timber in the basin except narrow strips in places along the creeks. The total drainage area of Devils Creek and its branches at its mouth is about 145 square miles, while that at the Santa Fe Railway bridge is about 143 square miles.

PRECIPITATION.

The storm causing the damage here discussed is described in the June issue of the Monthly Review of the Iowa Weather and Crop Service, as follows:

> On the afternoon and night of June 9 and morning of the 10th copious showers visited all districts, and in a considerable portion of the southeast and east-central districts the downpour can only be described by the term "torrential." The heaviest amounts reported at stations in the submerged

section were as follows: Bonaparte, 12.10 inches; Keosauqua, 11.09; Stockport, 10.63 (three cooperative stations in Van Buren County); Mount Pleasant, 7.20; Burlington, 6.10; Fort Madison, 6.40; Keokuk 4.80; Chariton, 4.22; Albia, 3.44; Iowa City, 4.87; Amana, 3.65; Davenport, 5.67; Wilton, 4.17; Le Claire, 4.41 inches. The larger part of this heavy precipitation fell in the twelve hours from 8.30 p. m of the 9th to 8.30 a. m. of the 10th, and in Bonaparte the average downpour was about an inch an hour The result of such a shower may be imagined but can not be fully described in detail. Not many buildings were sufficiently well roofed to keep the occupants dry, and but few streams and water courses were adequate to carry off the surplus moisture. Those who were driven into the wet say it came down in sheets and hit so hard it was difficult to stand, though there was no wind. One of the Van Buren County reporters states that 85 county bridges were swept away. The aggregate damage to crops by erosion of soil on slopes and flooding the bottoms was altogether beyond estimation in all the area swept over by that unprecedented storm. Happily such storms are not usual visitations.

The following table, prepared from data furnished by the United States Weather Bureau shows the depth of rainfall in inches at several surrounding places in Iowa and Illinois:

Precipitation at places in southeastern Iowa, June 9, 10, and during June, 1905, in inches.

Place.	June 9.	June 10.	Total for June.
Davenport, Iowa	3.93	1.69	7.68
Dubuque, Iowa	1.20	.38	4.33
Hannibal, Mo	.17	1.95	2.71
Keokuk, Iowa	2.18	2.62	6.57
La Harpe, Ill	.00	10.25	12.60

THE FLOOD.

Devils Creek at the Santa Fe Railway bridge began to rise about 10 p. m. and continued to rise gradually until about 12.30 a. m., when, according to the report of the bridge watchman, it rose about 4 feet in fifteen minutes. The bridge and about 150 feet of the right embankment went out about 4 a. m., when the water reached its maximum height, 17.7 feet above low water. This bridge was a Pratt truss bridge of 149-foot span, resting on masonry piers, with 54 feet of pile approach on the right side and 109 feet on the left. Fig. 6 shows a plan of this stream in the vicinity of the bridge; also a cross section and profile taken June 24, 1905, fourteen days after the flood. The waterway below the high-water line of June 10 had an area of 4,320 square feet before the flood and about 13,000 square feet after the flood. Thus it seems that the scouring effect at this bridge increased the waterway to three times its original size.

The daily gage heights and corresponding discharges at the United States Geological Survey gaging station on Des Moines River at Keosauqua, Iowa, from June 9 to 14, inclusive, were as follows:

Gage heights and discharge of Des Moines River at Keosauqua, Iowa, June 9–14.

Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*
June 9	4.0	8,550
June 10	22.8	75,750
June 11	14.4	44,670
June 12	10.6	30,610
June 13	8.1	21,460
June 14	5.6	13,250

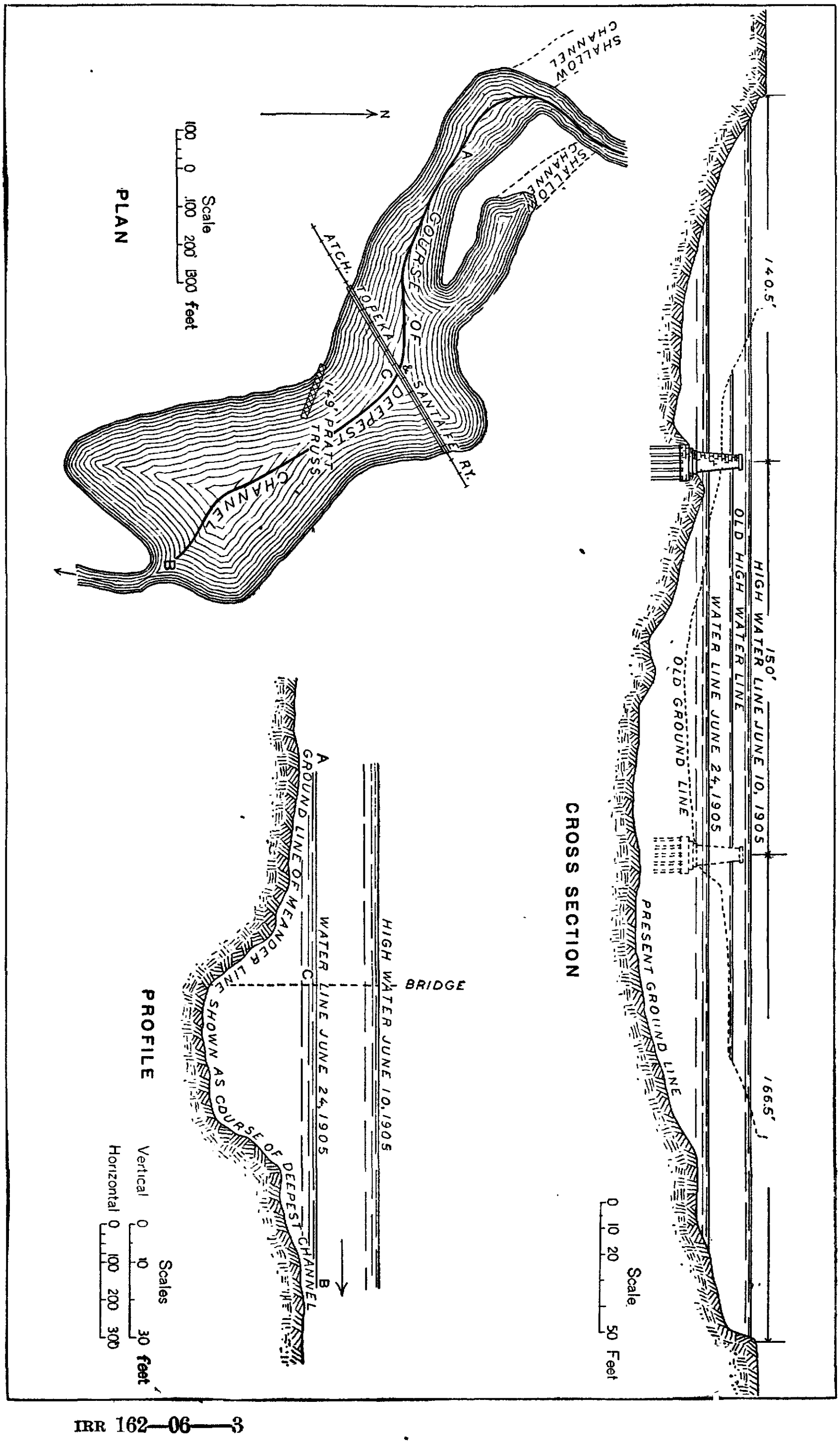


FIG. 6.—Plan and profile of Devils Creek at Atchison, Topeka and Santa Fe Railway crossing.

The table shows that the river at Keosauqua station rose from 4 feet on the 9th to 22.8 feet on the 10th, a total rise of 18.8 feet. Des Moines River at Des Moines rose on the 10th about 1 foot. Iowa River at Iowa City rose from 2.2 to 7.7 feet on the 10th. There was no rise on the 10th either in Cedar River at Cedar Rapids, Iowa, or in Rock River at Sterling, Ill. Skunk River is reported to have been very high, but there is no record of the amount of rise. Mississippi River at Fort Madison, Iowa, rose from 8 feet on the evening of the 9th to 11 feet on the morning of the 10th. The gage on the Mississippi River at Keokuk, Iowa, read 18.4 feet at 2 p. m. on the 10th. The maximum stage here in 1888 was 19.95 feet, the maximum in 1903 was 19.6 feet, and the maximum during the great flood of 1851 was 21.05 feet.

The high-water marks on Devils Creek show that the height of the flood and the flow were much greater on this creek than on either Panther or Little Devils Creek. The maximum rate of flow of this stream during this flood is very difficult to compute because it overflowed its banks and was from a quarter to a half a mile in width, except at some of the bridges. At the Santa Fe bridge Devils Creek was ultimately about 470 feet wide, but the stream bed was so much scoured that the cross section affords no basis for determining the size of the stream when the flow was at its maximum. Mr. Gray, the Santa Fe engineer in charge of the construction work at this bridge at the time of the flood, believes that the stream bed, which is of sand, scoured down to the clay previous to the time the bridge failed. The high-water marks above and below this bridge indicate a slope of 0.0025. The coefficient of roughness has been assumed to be 0.050. This high coefficient of roughness is necessary, owing to the many obstructions in the stream at the bridge. The channel is extremely crooked and the banks are covered with trees immediately above the bridge. The amount of pier and piling at the bridge was great, there being, in addition to the two piers on which the iron truss was supported, 54 feet of pile approach on one side and 109 feet on the other.[a] Undoubtedly immense amounts of drift were collected in and about these piers and piles. In addition to this there must be taken into consideration the effect of constriction of channel, for the stream immediately above the bridge was two or three times as wide as at the bridge. The hydraulic mean depth has been roughly computed from the maximum area to be 27.3 feet. From these data and the use of Kutter's formula, c being 56, v is found to be 14.6 feet per second; and the maximum rate of discharge is approximately 189,800 second-feet computed from the maximum cross-section area. Inasmuch as the drainage area of Devils Creek at the Santa Fe bridge is 143 square miles, this gives an approximate maximum run-off of 1,300 second-feet per square mile.

In order to verify this computation, an attempt has been made to compute, by means of Kutter's formula, the flow of the tributaries of Devils Creek. Considerable care has been exercised in selecting the proper coefficients of roughness and although at first they may seem somewhat large, yet an investigation of the conditions at the cross sections will show that they are proper. From data obtained at the Chicago, Burlington and Quincy Railway crossing on Devils Creek the maximum rate of discharge was found to be 161,600 second-feet, with a slope of 0.005 and a coefficient of roughness of 0.050; that at the crossing on the same line on Little Devils Creek was found to be 10,700 second-feet, with a slope of 0.002 and a coefficient of roughness of 0.040; and the maximum rate of discharge at the crossing of the Chicago, Burlington and Quincy Railway bridge on Panther Creek was found to be 7,300 second-feet, with a slope of 0.0028 and a coefficient of roughness of 0.038. The sum of these discharges is 179,000 second-feet. The drainage area of Devils Creek at the Santa Fe bridge exceeds the sum of the areas represented by the three points selected by about 2 square miles. Adding for this excess drainage area 1,300 second-feet per square mile to the discharge found by the summation of the partial discharges, there would be at the Santa Fe bridge over Devils Creek a discharge of 182,000 second-feet, which differs from the original computation by about 4 per cent.

[a] See Ganguillet and Kutter, flow of water, Theiss below Szolnok, Class B, Division VIII.

It has been noted that the run-off per square mile on the drainage area of Devils Creek at the Santa Fe bridge is about 1,300 second-feet. Like computations show that the run-off per square mile is about 1,500 second-feet, 560 second-feet, and 520 second-feet for Devils Creek, Little Devils Creek and Panther Creek, respectively, at points near Viele. This clearly indicates that the flood was concentrated in the main Devils Creek Valley.

These maximum rates of flow are greatly in excess of any that have been published for streams in the United States, and although the data were obtained with care they may be in error by a large amount. There was no engineer on the ground during this flood from whom definite information could be obtained as to what happened at each measured section at the time of maximum flow. Drift undoubtedly lodged in front of the Santa Fe Railway bridge and abutments, making a difference in elevation of the water surface above and below the bridge, and consequently a greater surface slope than the stream would show during times of free flow. Again, it is impossible to state with certainty the rate of scour of the bed and banks. The computed rate of flow is based on the area obtained from soundings taken on June 24, fourteen days after the flood. This area is three times larger than the area at this place just prior to the flood.

The behavior of Devils Creek at the bend (fig. 6), 1.5 miles above Viele, well illustrates the change of velocity in the channel around a bend when overflow takes place across the bend. This stream makes a sharp bend about 1,000 feet above the Chicago, Burlington and Quincy Railway bridge and flows nearly parallel with the railway. The overflow cut across this bend and entered the channel below with a velocity which was greater than that in the channel because of the same fall in a shorter distance. The entry of this overflow produced backwater in the channel above, reducing the velocity almost to zero. The overflow across the bend carried a steel bridge over the railway embankment, washed away the track, and eroded the embankment to a depth of 10 feet, but although the water was 3 feet deep on the railway bridge, the bridge was not damaged.

DAMAGE.

The damage done was very large considering the small area covered by the storm. In addition to the damage done at the Santa Fe Railway bridge No. 342, already mentioned, the Chicago, Burlington and Quincy Railway bridge over Devils Creek at Viele was swept away, with 375 feet of the right approach, and the abutments of the railway bridges over Little Devils and Painter creeks near Viele were badly damaged and 900 feet of embankment washed away. Besides these, 14 county bridges over Devils Creek in Lee County, varying in length from 70 to 127 feet; 6 bridges over the branches of Devils Creek, of lengths ranging from 30 to 156 feet; 4 bridges over Little Devils Creek, of lengths ranging from 110 to 136 feet; and 3 bridges over Panther Creek, of lengths ranging from 90 to 156 feet, were either swept away or damaged. The cost of replacing these county bridges was estimated at $27,000 by M. E. Bannon, bridge engineer, Lee County, Iowa. Many small bridges in this county were also swept away, and several miles of road and several acres of land were badly damaged by scour or by deposit of sand and débris upon it.

INFERENCES FROM FLOOD.

The general inference to be drawn from the effects of the high water on bridges throughout Devils Creek Valley is that all the waterways were by far too small. The waterways on the main stream were not more than one-third the size required to carry with safety the immense volume of water flowing at the time of the maximum stage. However, that it would not be economical and, therefore, not good engineering practice, to attempt to provide waterways sufficient for such extraordinary floods as that of June 10, 1905, is certain. The long lapse of time between storms of such abnormal proportions as the one here described makes the interest on the invested capital of the structure exceed several times the cost of replacement. The most economical bridge is one whose waterway is based on a careful study of the frequency and intensity of storms and the corresponding run-offs with a view to balancing interest on the first cost against cost of replacement, loss of traffic, etc., due to washouts.

Such engineering study is unfortunately hindered by lack of comprehensive data concerning rainfall. The washout experience of the railroads at their crossings on Devils Creek should result in enlargements of their waterways. That the new waterways need not be as large as the openings made by the flood, and that they should be larger than they were before the flood are equally without doubt.

The following table, taken from Table VI, Bulletin C, of the Weather Bureau, shows maximum rates of rainfall at points surrounding Lee County for periods prior to and including 1891.

Maximum rainfall at certain points in Mississippi River basin.

Location of station.	Period.	Maximum in 72 hours.	Maximum in 48 hours.	Maximum in 24 hours.
	Years.	*Inches.*	*Inches.*	*Inches.*
Dubuque, Iowa	32	5.8	5.4	4.5
Keokuk, Iowa	20	5.5	5.3	4.8
Omaha, Nebr	22	5.5	5.4	5.0
St. Louis, Mo	52	6.7	6.7	4.5
Cairo, Ill	20	5.7	5.2	4.2
St. Paul, Minn	22	5.1	4.6	3.7
Indianapolis, Ind	22	6.4	6.0	4.3

This table indicates that a rainfall of about 5 inches in twenty-four hours may be expected to occur at least as often as once in twenty years. It would therefore, seem wise to provide waterways for such storms as far as possible. It is a matter of record, as shown by the table below, that the major portion of the precipitation in these cases occurs in a few hours, and is not equally distributed throughout the twenty-four-hour period. It is also a well-known fact that as a rule these great rainstorms are local.

Heavy precipitation in upper Mississippi Valley.

Place.	Date.	Precipitation.	Time.	
		Inches.	*h.*	*m.*
Bright, Ind	September 23, 1898	2.00	2	
Kansas City, Mo	August 17, 1898	1.97	2	
Omaha, Nebr	July 6, 1898	0.98	1	53
Wheatland, Mo	July 29, 1898	2.54	2	
Oberlin, Kans	July 6, 1898	3.30	2	
Dresden, Kans	July 5, 1898	2.63	2	
Shelbyville, Ind	July 25, 1898	2.33	2	
Avalon, Mo	June 26, 1898	3.00	2	
Englewood, Kans	June 14, 1898	2.30	2	
Vevay, Ind	June 9, 1898	3.00	2	
Tilden, Ill	June 16, 1898	2.05	2	
Campbell, Kans	April 30, 1898	3.00	2	
Hannibal, Mo	March 26-27, 1889	2.90	2	
St. Louis, Mo	March 18, 1898	1.52	1	20
Columbia, Mo	October 28, 1900	1.92	1	20
St. Paul, Minn	September 11, 1900	1.39	1	20
Kansas City, Mo	September 27, 1900	1.33	1	20
Omaha, Nebr	June 16, 1900	2.19	1	20
Evansville, Ind	June 14 and 15, 1900	1.36	1	20
St. Paul, Minn	August 9, 1902	3.04	1	20
Columbia, Mo	August 18, 1902	2.04	1	20
Kansas City, Mo	July 1, 1902	3.37	1	20
Kansas City, Mo	August 13, 1903	1.35	2	

Let it be assumed, for streams with small drainage areas, that 60 per cent of the twenty-four-hour rainfall occurs in two hours; that it takes two hours for the storm water from the remotest part of the drainage area to reach a given point, and that the proportion of run-off is 70 per cent, for the per cent of run-off is often very large during heavy rains, as the ground is likely to be already thoroughly saturated. The amount of water reckoned in second-feet arriving at the lower end of this drainage area at the end of a two-hour period would be the total precipitation in cubic feet on that area for one second. Now, if F equals the number of square feet in a square mile; M, the member of square miles in the drainage area; P, the precipitation in feet for two hours; R, the percentage of run-off; T, the number of seconds in two hours, and Q, the maximum drainage area run-off; then,

$$Q=\frac{F\,M\,P\,R}{T}.$$

By substitution,

$$Q=\frac{5280\times5280\times\frac{3}{12}\times.70\,M}{2\times60\times60}=678\,M.$$

That is, there would be 678 second-feet per square mile to provide for. Evidently the rate of precipitation to be used should be the maximum occurring in the time required for the remotest waters to reach the point considered.

FLOOD IN DES MOINES COUNTY, IOWA.

On the night of August 15, 1898, a storm of great intensity occurred in Des Moines County, Iowa.[a] This storm and the damage done by it are discussed by Maurice Ricker in a paper entitled "The August Cloudburst in Iowa," read before the Iowa Academy of Sciences, December 28, 1898. This storm was confined to about two-thirds of Des Moines County, or an area of about 250 square miles. Unfortunately there were no rain gages in this area, but Mr. Ricker claims that reliable measurements of the depth of water in empty cans in exposed places indicate that over an area of about 50 square miles the precipitation was about 16 inches.

Twenty-three county bridges were swept away by this flood, and the Burlington, Cedar Rapids and Northern Railway lost 5 bridges and 2 miles of track by it.

FLOOD ON PURGATORY RIVER, COLORADO.

From April 22 to 24, 1905, 2.5 inches of rain and snow fell at Trinidid, Colo., and a greater depth on the mountains, causing a freshet in Purgatory River for several days. The stream has a fall of 42 feet per mile in the vicinity of Trinidad, and the sandy loam banks, softened by the rains, disappeared rapidly into the river. Many acres of fertile bottom land and thousands of feet of railway were swept away. The stream in places shifted its channel from one side of the valley to the other, necessitating the moving of some of the bridges.

Pl. I is a view of the river above Trinidad. On the right is a bridge, under which the river passed before the flood of September, 1904. The road and the right bank for several hundred feet were washed away. The railroads passing through Trinidad suffered heavily from these floods. All the trains on the Atchison, Topeka and Santa Fe Railway from Kansas City to the Southwest were delayed for several days. Large gangs of men were kept constantly at work repairing and rebuilding track washed out by the high water. About 2,000 feet of the pipe line that supplies the city of Trinidad with water were washed out, and the city was left without drinking water for several days.

---

[a] Monthly Review of the Iowa Weather and Crop Service, December, 1898.

The following table gives the gage heights and daily rate of flow of this stream at the gaging station near Barela, Colo., 30 miles below Trinidad and about one-eighth of a mile below the canyon entrance:

Flood flow of Purgatory River at entrance of canyon, Barela, Colo., April 23 to May 5, 1905.

Date.	Hour.	Gage height.	Hour.	Gage height.	Mean gage height.	Discharge.
	a. m.	*Feet.*	*p. m.*	*Feet.*	*Feet.*	*Sec.-feet.*
April 23	8. 45	4. 90	....	....	4. 90	261
April 24	8. 00	8. 60	1. 00	8. 00		
April 24	9. 00	8. 40	2. 00	7. 90		
April 24	10. 00	8. 20	3. 00	7. 80	8. 08	1,528
April 24	11. 00	8. 10	4. 00	7. 75		
April 24	12. 00	8. 10	5. 00	7. 70		
April 25	8. 45	7. 35	1. 45	7. 60		
April 25	9. 45	7. 35	2. 45	7. 90		
April 25	10. 45	7. 35	3. 45	8. 40	7. 96	1,456
April 25	11. 45	7. 40	4. 45	9. 30		
April 25	12. 45	7. 45	5. 45	9. 50		
April 26	8. 00	9. 80	1. 00	9. 70		
April 26	9. 00	9. 80	2. 00	9. 65		
April 26	10. 00	9. 80	3. 00	9. 60	9. 72	2,676
April 26	11. 00	9. 75	4. 00	9. 65		
April 26	12. 00	9. 70	5. 00	9. 65		
April 27	7. 30	11. 50	1. 00	10. 10		
April 27	8. 30	11. 30	2. 00	10. 00		
April 27	9. 30	11. 10	3. 00	10. 10	11. 01	3,790
April 27	10. 30	10. 75	4. 00	10. 50		
April 27	11. 00	10. 50	5. 00	10. 90		
April 27	12. 00	10. 40	....	....	....	....
April 28	8. 00	10. 80	5. 00	9. 90	10. 35	3, 198
April 29	8. 00	8. 90	5. 30	8. 30	8. 60	1, 860
April 30	7. 15	7. 90	5. 00	7. 50	7. 70	1, 305
May 1	8. 30	7. 70	5. 00	7. 30	7. 50	1, 195
May 2	8. 30	7. 30	....	....	7. 30	1, 095
May 3	8. 00	6. 80	....	....	6. 80	865
May 4	8. 00	6. 40	....	....	6. 40	695
May 5	8. 00	5. 80	4. 00	5. 90	5. 85	495

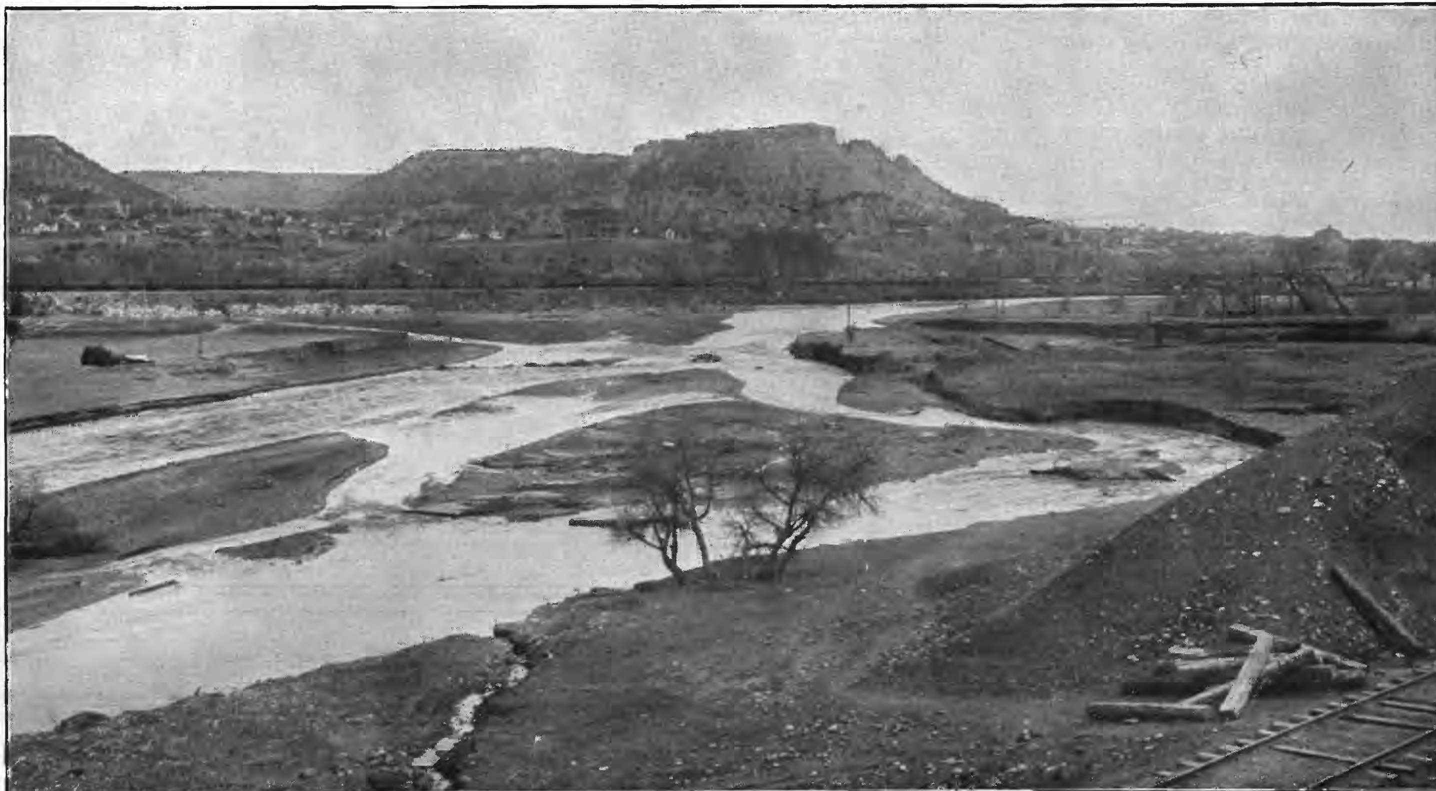
It is seen that the largest recorded gage height was 11.50 feet, on the morning of the 27th. The gage reader reports that on the night of the 26th the water reached the 15-foot mark on the gage. The discharge for a 15-foot stage is upward of 7,700 second-feet.

FLOOD ON PECOS RIVER, NEW MEXICO-TEXAS.

During the latter part of July a flood occurred on the Pecos River that approached closely in magnitude the great flood of September and October, 1904, in that part of the stream from Carlsbad, N. Mex., to Pecos, Tex. The flood did much damage to bridges and irrigation works.

Pecos River rises in the northern part of New Mexico, flows in a southerly and southeasterly direction a distance of 550 miles, and empties into the Rio Grande near Langtry, Tex.

The following table gives the daily gage height at Santa Rosa and Roswell and the daily gage height and corresponding discharge at Carlsbad and Pecos, Tex., during the flood.



PURGATORY RIVER AT TRINIDAD, COLO.

Daily rate of flow of Pecos River during floods of 1905.

Date.	Santa Rosa, N. Mex.	Roswell, N. Mex.	Carlsbad, N. Mex.		Pecos, Tex.	
	Gage height.[a]	Gage height.[b]	Gage height.[c]	Discharge.	Gage height.[d]	Discharge.
	Feet.	*Feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
July 20	0.7	3.3	0.99	206	0.9	140
July 21	0.9	3.0	1.48	476	0.9	140
July 22	2.5	3.0	1.54	518	0.9	140
July 23	1.5	10.0	2.77	1,504	1.0	150
July 24	1.5	6.0	8.67	18,620	4.9	1,600
July 25	1.5	6.7	[e]14.39	47,600	7.2	5,380
July 26	1.0	5.6	12.42	37,500	9.4	8,450
July 27	1.0	4.3	10.00	25,000	13.7	16,100
July 28	1.0	3.8	7.00	11,300	18.3	25,500
July 29	1.0	3.4	5.35	5,685	17.2	22,650
July 30	1.0	3.4	4.50	3,750	13.2	15,200
July 31	1.0	3.4	4.15	3,140	10.7	9,750
August 1					7.6	5,800
August 2					6.2	4,170

[a] Maximum stage during flood of October, 1904, 23 feet.
[b] Maximum stage during flood of October, 1904, 16.5 feet.
[c] Maximum stage during flood of October, 1904, 15+feet.
[d] Maximum stage during flood of October, 1904, 19 feet.
[e] Gage height at 10 a. m., 15.85 feet; discharge, 54,930 second-feet.

It is seen that the stream above Santa Rosa was not in flood at this time, as the gage did not read above 2.5 feet, not within 21 feet of the gage reading of September 30, 1904. At Roswell the maximum stage was 7 feet; it was 16.5 feet on October 1, 1905. The maximum stage at Carlsbad occurred on July 25, and was at least 1.4 less than in October, 1904. At Pecos, Tex., the highest stage was reached on July 28, and was about a foot less than the highest stage in October, 1904. The Pecos did not begin to rise at the mouth until July 30. It rose slowly from a stage of 1.7 feet and a rate of flow of 670 second-feet on July 29 to a stage of 5.6 feet and a rate of flow of 5,530 second-feet on August 12.

The total run-off of the Pecos at Carlsbad, N. Mex., for the nine days, July 23–31, of this flood was 305,600 acre-feet.

By comparing the gage heights and corresponding rates of flow given in the table above with those prevailing during the flood of September and October, 1904,[a] it will be seen that the flood of 1905 was much smaller than the flood of 1904 above Carlsbad and almost disappeared above Santa Rosa. In the vicinity of Pecos, Tex., the flood of 1905 almost equaled in magnitude that of 1904, but was of shorter duration. The stage was 9 feet or more for twelve days in 1904 and only six days in 1905.

[a] See Water-Supply and Irrigation Paper, U. S. Geol. Survey, No. 147, p. 133.

FLOOD ON HONDO RIVER, NEW MEXICO.

The Hondo reached a higher stage at Hondo reservoir during 1905 than during 1904.

The following table gives the daily gage height and discharge at Hondo reservoir during the flood of 1905:

Daily rate of flow of Hondo River during floods of July, 1905.

Date.	Reservoir.		Roswell.	
	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
July 22	Dry.			
July 23	6.3	460		
July 24	8.05	820	4.1	422
July 25	11.4	1,790	5.0	551
July 26	9.2	1,115	5.7	660
July 27	8.55	950	4.9	535
July 28	7.0	600	4.85	528
July 29	6.5	500	3.6	358
July 30	4.15	170	2.95	280
July 31	4.35	250	2.25	202

FLOOD ON RIO GRANDE, NEW MEXICO-TEXAS.

INTRODUCTION.

From May 15 to June 20 the part of this stream between Albuquerque, N. Mex., and Presidio, Tex., was in destructive flood. The dikes protecting villages and lowlands were overtopped and considerable damage was done to crops, railway property, buildings, and land along the river. It was the spring flood, due to the rapid melting of an exceptionally large winter accumulation of snow on the mountains.

The Rio Grande rises among the mountains of southern Colorado, flows in a general southerly and southeasterly direction for about 1,800 miles, and empties into the Gulf of Mexico. Its two largest tributaries are the Pecos, entering from the north near Morehead, Tex., and the Rio Conchos, entering from the south at Presidio, Tex. (see fig 7). It is a storm-water stream, subject to large and sudden fluctuations of flow, except in the spring and early summer, when its water comes from melting snow in the mountains at the headwaters. The basin is long and comparatively narrow, the larger part being mountainous, with steep, barren, impervious slopes. From its head to Del Norte, Colo., a distance of 144 miles, the fall of the stream is 4,258 feet; from Del Norte to San Marcial, 393 miles, the fall is 3,342 feet; from San Marcial to El Paso, 203 miles, it is 700 feet; from El Paso to the mouth, 1,032 miles, it is 3,700 feet. The area of the watershed above El Paso is 38,000 square miles.

FLOOD FLOW.

There are eight gaging stations on this stream. The daily rate of flow and progress of

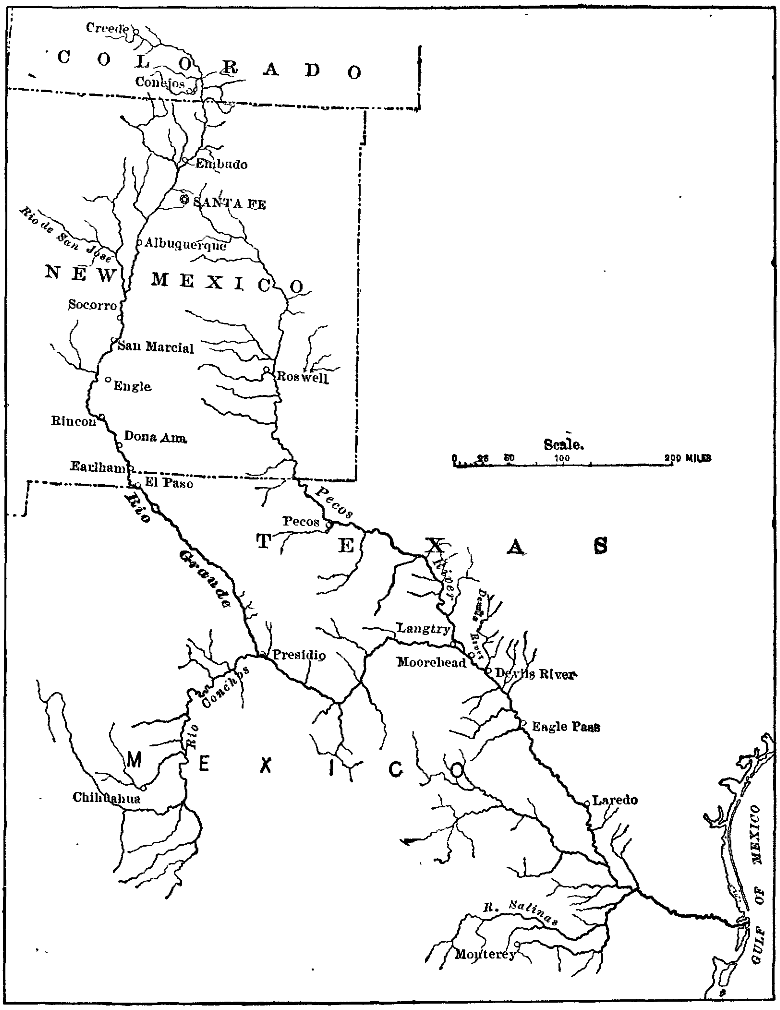


FIG. 7.—Map of Rio Grande drainage basin.

the flood down the stream can be seen from the record at San Marcial, El Paso, and Upper Presidio,[a] given in the following table:

[a] Data furnished by W. W. Follett, consulting engineer.

Flood flow of Rio Grande during part of May and June, 1905.

Date.	Cenicero (gage height).	Rio Grande (gage height).	San Marcial (discharge).	El Paso (discharge).	Upper Presidio (discharge).
	Feet.	*Feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*
May 19	5.9	11.1	15,380	6,020	....
May 20	6.6	11.6	16,550	6,180	....
May 21	7.0	11.5	17,350	6,980	....
May 22	7.2	11.4	23,400	8,360	....
May 23	7.7	11.5	28,600	9,720	....
May 24	7.95	11.8	29,070	9,800	....
May 25	8.0	11.8	23,540	10,210	4,800
May 26	8.4	11.5	28,000	12,640	4,900
May 27	8.15	11.2	27,100	14,720	5,050
May 28	8.0	10.9	25,580	16,450	5,200
May 29	7.7	10.6	23,600	17,860	5,200
May 30	7.1	10.5	20,430	18,920	5,400
May 31	6.7	9.4	19,060	18,920	5,650
June 1	6.25	9.3	19,360	20,270	5,850
June 2	6.5	9.1	19,660	20,720	6,200
June 3	7.05	9.2	19,970	20,320	6,500
June 4	7.85	9.5	17,110	18,840	6,900
June 5	8.25	10.2	16,350	17,620	7,480
June 6	8.75	10.5	16,480	15,630	8,860
June 7	8.85	10.45	15,810	14,190	9,640
June 8	9.05	10.7	15,440	14,190	10,620
June 9	8.85	11.1	15,070	17,410	11,200
June 10	8.6	10.4	15,930	18,300	11,780
June 11	8.45	10.05	17,390	20,190	12,360
June 12	8.1	9.65	18,460	23,680	12,540
June 13	7.6	9.4	16,370	23,050	13,700
June 14	6.8	9.05	13,570	23,620	13,700
June 15	6.7	8.45	12,170	23,270	12,600
June 16	6.4	8.15	11,880	23,270	12,400
June 17	6.3	7.7	12,800	20,100	12,600
June 18	6.05	7.5	13,730	17,250	11,400
June 19	5.8	7.15	10,950	13,620	12,300
June 20	5.15	6.85	10,170	9,970	12,100
June 21	4.9	6.45	8,810	7,310	11,900
Total flow, in acre-feet	....	....	1,276,000	1,070,000	513,400

There were evidently two flood waves, one reaching a maximum rate of 29,070 second-feet at San Marcial on May 24, the other reaching a maximum of 18,460 second-feet at San Marcial on June 12, nineteen days later. These two waves reached El Paso on June 2 and 14, the second having there a larger rate of flow than the first. The first wave was lost before reaching Presidio, and the maximum rate of the second one at that place was reduced to 13,700 second-feet. The total volume of flow from May 19 to June 21 at San Marcial is 1,276,000 acre-feet. The total volume at El Paso May 19 to June 21 is 1,070,000 acre-feet, and the total volume at Presidio May 25 to June 21 is 513,400 acre-feet.

COMPARISON WITH FLOOD OF OCTOBER, 1904.

The following table gives the daily rate of flow at San Marcial and El Paso for the ten days of the flood of 1904 between October 8–17, and for ten days of the flood of May, 1905. The former, a fall flood due to rain, had a much more rapid rate of rise and fall and a greater maximum rate of flow than the latter, which was a spring flood, due to melting snow. The greatest daily discharge each year from 1895 to 1905 is given on page 83.

Comparison of daily discharge of Rio Grande at San Marcial and El Paso during the floods of 1904–1905.

Date.	1904. San Marcial.	1904. El Paso.	Date.	1905. San Marcial.	1905. El Paso.
	Sec.-feet.	*Sec.-feet.*		*Sec.-feet.*	*Sec.-feet.*
October 8	2,880	5,740	May 21	17,350	6,980
October 9	12,000	7,670	May 22	23,400	8,360
October 10	24,000	11,370	May 23	28,600	9,720
October 11	33,000	10,550	May 24	29,070	9,800
October 12	24,800	12,010	May 25	23,540	10,210
October 13	21,750	13,800	May 26	28,000	12,640
October 14	15,900	16,200	May 27	27,100	14,720
October 15	11,100	17,100	May 28	25,580	16,450
October 16	6,250	9,300	May 29	23,600	17,860
October 17	1,550	6,300	May 30	20,430	18,920

DAMAGE.

The damage done by this flood consisted chiefly in the destruction of crops on lands overflowed and the destruction of clay or adobe buildings. The village of Tome, 35 miles south of Albuquerque, N. Mex., one of the oldest in the Territory, was reported to have been almost completely destroyed. The river broke through the dike at this place, flooded the village, softened the walls of the buildings, and caused them to fall. Some of the land along the river was injured by having the soil washed from it, while other land was enriched by the deposition of rich sediment upon it.

EFFECT OF PROPOSED ENGLE DAM ON FLOODS.

A reservoir, to be formed by a dam on the Rio Grande, will be located near Engle, N. Mex., 125 miles above El Paso. It will have a depth of 175 feet at lower end, a length of 40 miles, and a capacity of 2,000,000 acre-feet. The following table gives run-off, in acre-feet, at San Marcial each month from October, 1904, to September 30, 1905, and the total volume for these twelve months.

Estimated monthly discharge of Rio Grande near San Marcial, N. Mex., October 1, 1904, to September 30, 1905.

Month.	Maximum.	Minimum.	Mean.	Total in acre-feet.
1904.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	
October	33,000	1,120	7,534	463,200
November	1,430	650	870	51,770
December	1,130	355	679	41,750
1905.				
January	1,005	370	636	39,110
February	3,220	290	1,150	63,870
March	5,620	2,200	3,544	217,900
April	14,160	1,730	4,695	279,400
May	29,070	7,500	15,650	962,200
June	19,970	2,640	12,000	714,300
July	2,770	65	582	35,780
August	710	0	327	20,090
September	470	0	89	5,276
Acre-feet for period				2,895,000

It is seen that the total flow for these twelve months at San Marcial was about 1.45 times the capacity of this reservoir.

SPRING FLOODS IN COLORADO RIVER BASIN.

INTRODUCTION.

In the Colorado River drainage basin, especially its southern portion, a remarkable flood or succession of floods occurred during the period January-April, 1905. The rate of flow of some of the tributaries may have been greater, for a short time, at some previous date than during this period, but the total run-off of the Gila and Colorado during this flood was unprecedented. The flood of 1903 on the Colorado was regarded as one of the largest up to that time, but the total run-off at Yuma from January to July, 1905, was 1.8 times greater than during the corresponding period of 1903. The Gila River at Dome, near its mouth, had a total run-off of 31,000 acre-feet from January to May, 1903, inclusive, and 2,957,800 acre-feet for the same period of 1905.

The Colorado River proper is formed by the junction of the Green and Grand rivers in the southern part of Utah, flows in a general southwesterly direction for nearly 1,000 miles, and empties into the Gulf of California. The principal tributaries are the Gila, Little Colorado, San Juan, Virgin, and Williams. The following table, prepared mainly from data in Water-Supply and Irrigation Paper No. 44 (p. 82), gives the distance from the mouth to places along the river, their height above sea level, and the fall per mile between them.

Distances and altitudes along Colorado River, and fall per mile.

Locality.	Distance from mouth.	Height above sea.	Fall per mile.
	Miles.	*Feet.*	*Feet.*
Mouth	0	0	0
Yuma (mouth of Gila River)	150	125	0.8
Ehrenberg	261	....	....
Mouth of Williams River	340	375	1.3
Needles Bridge	367	....	....
Needles	385	448	1.6
Mohave City	440	....	....
Hardyville	447	....	....
Bullshead	454	....	....
Mouth of Virgin River	555	935	2.9
Mouth of Grand Wash (fault)	600	1,000	1.4
Mouth of Diamond Creek	650	1,312	6.2
Toroweap Valley (fault)	700	1,625	6.3
Mouth of Kanab Creek	730	1,810	6.2
	790	2,300	8.2
	800	2,520	22.0
Mouth of Little Colorado River	815	2,625	7.0
Mouth of Paria River	880	3,187	8.6
Mouth of Navajo Creek	905	3,220	1.3
Crossing of the Fathers	920	3,250	2.0
Mouth of San Juan River	957	3,310	1.6
Mouth of Escalante River	970	3,325	1.2
Mouth of Dirty Devil River	1,030	3,434	1.8
	1,067	3,750	31.2
Mouth of Grand River	1,080	3,775	1.9

The Colorado River drainage basin, including the Green and Grand rivers, extends from 43.5° to 31° north latitude, and from 115.5° to 106° west longitude, and comprises an area of about 225,000 square miles. Within this basin is found some of the most varied topography on this continent. The canyon of the Colorado has a depth of 3,000 to 6,000 feet below the surrounding plateaus. The greater part of the basin consists of elevated plateaus bordered with cliffs. The slopes are steep and nearly impervious, hence the run-off is very rapid.

PRECIPITATION.

The mean annual precipitation varies from less than 5 inches in the southwestern part of the basin to more than 15 inches on some of the high plateaus and mountains. On the headwaters of the Duchesne River the precipitation must be more than 20 inches, as the measured annual run-off is 14.5 inches.

The following table, prepared from the records of the United States Weather Bureau gives the monthly precipitation from January to April, 1905, at places in the Gila River basin and vicinity. It also gives the mean monthly precipitation at some of these places for comparison:

Monthly precipitation in the Gila and Little Colorado River basins from January 1 to April 30, 1905, compared with the mean monthly precipitation of same localities.

Place.	January.		February.		March.		April.		Total.	
	1905.	Mean.	1905.	Mean.	1905.	Mean.	1905.	Mean.	1905.	Mean.
Jerome, Ariz	5.10	1.44	7.80	2.35	7.30	1.35	3.70	1.07	23.90	6.21
Prescott, Ariz	4.74	1.55	7.92	1.76	6.17	1.78	3.81	0.81	22.64	5.90
Seligman, Ariz	1.97	......	3.27	......	2.16	......	1.65	......	9.05	......
Alma, N. Mex	1.44	0.99	6.05	0.39	5.35	0.56	2.40	0.38	15.24	2.32
Young, Ariz	5.21	......	7.94	......	7.50	......	4.59	......	25.24	......
Alpine, Ariz	3.15	......	5.88	......	4.91	......	3.20	......	17.14	......
Fort Apache, Ariz	3.45	1.36	4.31	1.80	6.79	1.63	5.00	0.71	19.55	5.50
Fort Grant, Ariz	0.36	0.99	2.34	1.13	0.99	0.71	1.21	0.32	4.90	3.15
Phoenix, Ariz	3.31	0.80	4.64	0.70	2.38	0.58	2.59	0.44	12.92	2.52
Oro, Ariz	3.61	1.03	6.22	1.21	6.07	0.98	2.35	0.41	18.25	3.63
Deming, N. Mex	1.53	0.43	2.08	0.31	2.15	0.42	1.87	0.06	7.63	1.22
Fort Bayard, N. Mex	3.07	0.66	4.26	0.86	4.33	0.58	2.93	0.24	14.59	2.34
San Carlos, Ariz	3.46	1.33	5.03	1.44	3.30	0.98	3.34	0.42	15.13	4.17
Cambray, N. Mex	1.69	0.22	2.01	0.60	1.02	0.23	0.55	0.02	5.27	1.07
Bowie, Ariz	1.91	1.63	3.29	1.15	2.65	0.92	1.19	0.21	9.04	3.91
Gage, N. Mex	......	......	3.00	0.37	2.95	0.37	1.78	0.03	7.73	......
Dudleyville, Ariz	3.57	1.35	5.88	1.39	3.75	1.02	3.90	0.54	17.10	4.30
Lordsburg, N. Mex	1.57	0.53	3.35	0.32	3.24	0.44	1.27	0.09	9.43	1.38
Mesa, Ariz	2.85	1.27	4.86	0.94	3.42	0.76	2.70	0.45	13.83	3.42
Luna, N. Mex	2.09	......	3.53	......	2.47	......	2.37	......	10.46	......
Buckeye, Ariz	2.91	1.08	6.46	0.80	3.61	0.72	2.04	0.22	15.02	2.82
Maricopa, Ariz	1.60	0.74	2.70	0.70	1.72	0.45	1.71	0.14	7.73	2.03
Yuma, Ariz	1.15	0.42	3.43	0.51	3.33	0.26	0.16	0.08	8.07	1.27
Bisbee, Ariz	1.12	......	5.71	......	5.26	......	4.04	......	16.13	......
Benson, Ariz	1.08	......	3.34	......	4.20	......	2.01	......	10.63	......
Duncan, Ariz	2.10	......	3.72	......	3.36	......	1.74	......	11.92	......
Holbrook, Ariz	1.29	......	2.98	......	2.93	......	1.57	......	8.77	......
Kingman, Ariz	1.77	......	4.47	......	3.05	......	2.42	......	11.71	......
Fort Wingate, N. Mex	2.30	......	2.31	......	2.85	......	4.05	......	11.51	......
Flagstaff, Ariz	3.20	......	5.79	......	4.02	......	2.65	......	15.66	......
Tuba, Ariz	1.45	......	1.21	......	0.96	......	2.58	......	6.20	......

It is seen that the precipitation for this period at all of these places was several times greater than the normal. At some places where the rainfall per month is generally about one-half inch it was from 5 to 7 inches per month. Excessive precipitation for a short time over comparatively small areas is not uncommon, but such long periods of excessive rainfall over so large an area in this section is very remarkable. In a considerable part of the Salt and Verde River basins the precipitation during these four months was over 20 inches.

TRIBUTARIES OF COLORADO RIVER ABOVE HARDYVILLE.

The subjoined table shows the discharge of tributaries of the Colorado during the floods of June, 1905:

Daily rate of flow of Colorado, Green, Grand, Gunnison, and San Juan rivers, during floods of June, 1905.

[Drainage areas above gaging stations in square miles: Green River, 38,200; Grand River, 8,546; Gunnison River, 7,863.]

Day.	Colorado River at Hardyville, Ariz.		Green River at Greenriver, Utah.		Grand River at Palisade, Colo.		Gunnison River at Whitewater, Colo.		San Juan River at Farmington, N. Mex.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
1					19.35	25,040	11.65	17,780	10.05	15,650
2					20.05	29,200	12.45	21,280	10.7	17,600
3					20.35	31,000	12.75	22,710	12.4	22,700
4					21.0	35,000	13.15	24,660	12.25	22,250
5	10.8	64,310	9.6	29,260	22.05	41,620	13.85	28,080	12.35	22,550
6	11.85	73,890	9.8	30,970	22.0	41,300	13.6	26,860	13.10	24,800
7	12.5	80,070	9.85	31,400	21.8	40,020	13.05	24,160	11.65	20,450
8	13.1	85,880	10.05	33,160	21.35	37,180	13.2	24,900	11.8	20,900
9	13.7	91,760	10.3	35,400	22.0	41,300	13.5	26,370	12.0	21,500
10	14.4	98,620	10.55	37,700	22.0	41,300	13.55	26,620	11.9	21,200
11	14.3	96,500	10.5	37,230	21.3	36,860	12.95	23,680	12.0	21,500
12	14.0	93,500	10.05	33,160	21.25	36,850	12.5	21,520	12.05	21,650
13	14.3	94,000	10.2	34,500	20.6	32,530	12.25	20,360	11.9	21,200
14	14.45	94,500	10.2	34,500	20.35	31,000	12.05	19,460	11.6	20,300
15	14.5	93,500	9.95	32,280	20.4	31,310	11.85	18,600	11.4	19,700
16	13.8	85,500	9.85	31,400	20.4	31,310	11.7	17,980	11.4	19,700
17	13.3	79,000	9.35	27,180	19.9	28,300	11.1	15,680	11.75	20,750
18	12.8	73,000	9.25	26,370	19.45	25,620	10.45	13,420	10.6	17,300
19	12.5	70,500	9.15	25,580	19.05	23,290	10.15	12,440	10.7	17,600
20	12.2	67,500	9.05	24,790	18.7	21,300	9.9	11,650	10.75	17,750

GREEN RIVER AT GREENRIVER, UTAH.

The daily rate of flow of Green River, the largest of the two streams that form the Colorado, at the gaging station near Greenriver, is given on page 40. The station is located about 70 miles above the mouth of the river and the drainage area above this point is 38,200 square miles.

The stage increased gradually from 9.6 feet on June 5 to 10.55 feet on June 10, and the rate of flow increased from 29,260 second-feet to 37,700 second-feet. From the 11th to the 20th the rate of flow gradually decreased from 37,230 second-feet to 24,790 second-feet. The greatest daily rate of flow was about 1 second-foot per square mile. In May, 1897, the rate of flow was 68,800 second-feet, and in June, 1899, it was 58,350 second-feet.

GRAND RIVER AT PALISADE, COLO.

The daily rate of flow of Grand River, which unites with the Green to form the Colorado at the gaging station at Palisade, Colo., is given on page 40. Between June 2 and June 16 the stage varied from 20 to 22 feet and the rate of flow from 29,000 to 41,300 second-feet.

The greatest daily rate during this period was 4.83 second-feet per square mile. This station was established in 1902. The greatest rate of flow during these four years prior to June, 1905, was 24,800 second-feet in May, 1904.

GUNNISON RIVER AT WHITEWATER, COLO.

The daily rate of flow of Gunnison River during this flood at the gaging station, 10 miles above its mouth, is given on page 40. From June 1 to June 16 the stage varied from about 11.7 to 13.85 feet and the rate of flow from 17,780 to 28,080 second-feet. The maximum daily rate during this time was 3.67 second-feet per square mile. This station has been in operation four years. The greatest daily rate during this period prior to June, 1905, was 17,810 second-feet in June, 1903.

SAN JUAN RIVER NEAR FARMINGTON, N. MEX.

The San Juan is the largest tributary of the upper Colorado, which it enters from the east about 120 miles below the junction of the Green and the Grand, and about 15 miles north of the Utah-Arizona boundary line. The daily rate of flow at the gaging station near Farmington, N. Mex., is given on page 40. From June 1 to June 21, the stage varied from about 10 to 13.1 feet, and the rate of flow from 15,600 to 24,800 second-feet. The greatest daily rate in 1904 was 20,000 second-feet in October.

LITTLE COLORADO RIVER.

The excessive precipitation in the basin of the Little Colorado during the months January-April, noted on page 39, resulted in great floods that swept away several large dams and deprived many thousand acres of irrigated land of water.

A gaging station was established on this stream at Holbrook, Ariz., March 17, after the largest flood that destroyed the dams had passed. The records at this place show that during the period, March 17 to April 30, the discharge varied from 1,000 to 2,075 second-feet.

The maximum stage, due to failure of the St. Johns dam, was 11.5 feet. This stage is about 3 feet higher than that on November 29, when the discharge was estimated to have been about 20,000 second-feet.

COLORADO RIVER AT HARDYVILLE, ARIZ.

A gaging station is located on Colorado River about one-fourth of a mile above the deserted town of Hardyville, 7 miles above Fort Mohave and 297 miles above Yuma. Discharge measurements are made from a car on a cable, and fluctuations of stage are read daily on a rod fastened to the left bank near the cable.

The daily gage height and rate of flow from June 5 to June 20, during this flood, are given on page 40.

At this station there was a gradual increase from a stage of 10.8 feet and a discharge of 64,310 second-feet, on June 5, to a stage of 14.4 feet and a discharge of 98,620 second-feet on June 10. From June 10 to June 15 the stage varied from 14 to 14.5 feet. On the 20th it had fallen to 12.2 feet.

GILA RIVER BASIN.

INTRODUCTION.

Gila River rises in the mountainous country of southwestern New Mexico, flows in a general southwesterly direction through Arizona, and empties into Colorado River 1 mile above Yuma, Ariz. Its principal tributaries are the Salt, Verde, San Francisco, Agua Fria, and Hassayampa from the north and the San Pedro and Santa Cruz from the south. The location of these streams is shown on Pl. II.

The total area drained by this river is 71,140 square miles, 40 per cent of which has an elevation of less than 3,000 feet and is largely agricultural land if supplied with water. About

27 per cent has an elevation of more than 5,000 feet and from this part comes the water supply. This high plateau, which lies at the headwaters of the Gila, in the eastern and northeastern part of the drainage basin, intercepts the moisture-laden winds from the southwest and causes them to precipitate their moisture. The run-off from the remaining 73 per cent is small, except during an occasional period of heavy storms like that of the winter and spring of 1905. The run-off is rapid, the slopes being steep and impervious and the fluctuations in flow are very great, as can be seen from fig. 8.

PRECIPITATION.

The precipitation in this basin during the floods of 1905 can be seen from the precipitation records on page 39. Large parts of the Salt, Verde, and Gila basins are in the area of greatest precipitation, and more than 20 inches of rain fell on them during these four months.

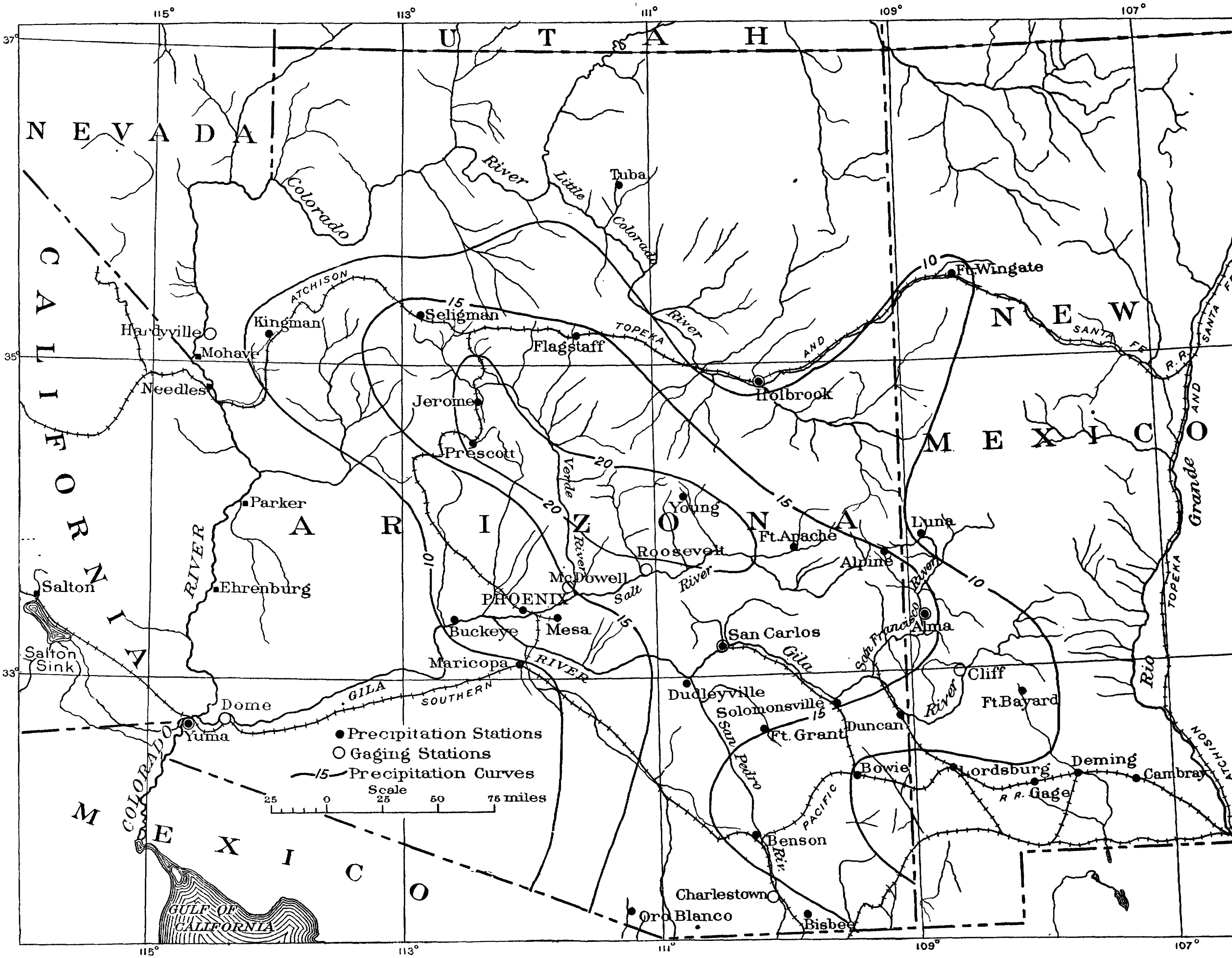
SAN FRANCISCO RIVER.

The San Francisco is an important tributary of the Gila, which it enters from the north about 30 miles above Solomonsville, Ariz. The gaging station on it is located at Alma, N. Mex. The basin above the station is mountainous and comprises an area of about 18,000 square miles. The following table gives the daily rate of flow at this station during these floods:

Daily discharge, in second-feet, of San Francisco River at Alma, N. Mex., in 1905.

[Drainage area, 1,800 square miles.]

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
January 9	80	March 7	910	April 4	1,380
January 10	3,162	March 8	2,120	April 5	1,932
January 11	1,080	March 9	325	April 6	1,874
January 12	357	March 16	230	April 7	1,758
February 3	287	March 17	3,092	April 8	1,590
February 4	910	March 18	2,164	April 9	1,245
February 5	910	March 19	1,700	April 10	1,245
February 6	1,310	March 20	2,280	April 11	1,200
February 7	560	March 21	1,590	April 12	1,430
February 8	370	March 22	1,480	April 13	1,990
February 16	200	March 23	1,480	April 14	1,400
February 17	4,760	March 24	1,290	April 15	1,200
February 18	5,060	March 25	1,110	April 16	975
February 19	180	March 26	1,110	April 22	618
February 27	340	March 27	1,020	April 23	1,535
February 28	4,010	March 28	885	April 24	1,700
March 1	3,410	March 29	800	April 25	1,380
March 2	2,360	March 30	602	April 26	1,020
March 3	2,510	March 31	642	April 27	930
March 4	2,510	April 1	681	April 28	1,020
March 5	2,660	April 2	1,155	April 29	760
March 6	460	April 3	2,048	April 30	602



DRAINAGE BASIN OF GILA RIVER, ARIZONA.

GILA RIVER NEAR SOLOMONSVILLE, ARIZ.

For 20 miles below the mouth of the San Francisco the Gila flows in a canyon. About 10 miles above Solomonsville the topography changes, and from this place to a point 6 miles below San Carlos—nearly 70 miles—the river flows in a fertile valley where irrigation ditches take water from it on both sides. This is one of the finest irrigated portions of Arizona.

Great damage was done in this valley by the floods of 1905. The banks of the river are composed of sandy loam which is easily eroded, and several hundred acres of land were washed away. The stream bed was doubled or trebled in width by these floods and is now strewn with uprooted trees that before the flood grew along the banks. On some areas that were protected from the direct scouring action of the current material has been deposited to depths ranging from 6 inches to 4 feet, destroying the land for agricultural purposes. The irrigation works, especially the ditches, were badly damaged, many orchards and fields of alfalfa were destroyed or badly injured, the railway bridge at San Carlos was washed away in January, the railway along the river was damaged several times at many places, and traffic was interrupted for the greater part of the time from January 10 to April 15.

During the flood of January 11 the Gila rose very rapidly in the vicinity of Solomonsville and overflowed all the land below the level of the Montezuma canal. It overflowed the river bank above the heads of this canal, flowed through the city, and before the canal could be cut to allow the water to pass back into the river many adobe houses were destroyed.

The gage at the gaging station at San Carlos was washed away on January 10 at a river stage of 5½ feet above ordinary water. A new gage was put in February 1 and during February the stage varied from 1.8 feet to 9 feet. This gage was washed away March 17 at a stage of 8 feet. The bed of the stream was changed so much during these floods that reasonably accurate estimates of the daily rate of flow at this place can not be given.

The daily rate of flow from June 27 to July 14 varied from 4 to 6 second-feet. The maximum rate of flow during these floods was 5,060 second-feet, or 2.8 second-feet per square mile.

A large amount of damage was done by these floods in the vicinity of Clifton, Ariz. The steel railway bridge across the river was swept away, the roadbed was damaged, and traffic interrupted for several days, a few small buildings were swept away, and the smelters along the river were damaged.

SAN PEDRO RIVER.

The San Pedro enters the Gila from the south at Dudleyville, Ariz. The total area drained by it is 3,456 square miles. The greatest rate of flow in January was 124 second-feet, in February 235 second-feet, in March 668 second-feet, and in April 145 second-feet. As this gaging station is about 110 miles above the mouth of the river, these figures afford little indication of the rate of flow at the mouth.

SALT RIVER.

Salt River is the largest tributary of the Gila, which it enters from the north 14 miles west of Phoenix, Ariz. Its principal tributaries are the Verde, entering from the north at McDowell, and Tonto Creek, entering from the north at Roosevelt. The basin of the Salt above the mouth of the Verde is mountainous, with deep canyons and very steep slopes.

The precipitation at places in this basin during January-April is given on page 39.

The daily rate of flow during the floods of these four months as measured at the gaging station at Roosevelt, Ariz., is given in the following table:

Daily discharge, in second-feet, of Salt River at Roosevelt, Ariz., during floods of January–April, 1905.

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
January 9	346	March 1	17,100	March 28	6,740
January 10	5,900	March 2	12,150	March 29	6,000
January 11	12,300	March 3	9,250	March 30	6,700
January 12	9,460	March 4	8,925	March 31	7,300
Januray 13	4,000	March 5	11,300	April 1	7,548
January 14	2,400	March 6	11,330	April 2	8,076
January 15	1,685	March 7	11,220	April 3	9,819
January 16	1,513	March 8	11,060	April 4	12,020
January 17	1,341	March 9	11,220	April 5	8,937
January 18	1,170	March 10	11,540	April 10	8,937
January 19	999	March 11	11,500	April 11	20,040
February 2	625	March 12	8,200	April 12	43,350
February 3	3,900	March 13	22,050	April 13	45,470
February 4	31,400	March 14	38,700	April 14	20,370
February 5	18,800	March 15	17,600	April 15	14,010
February 6	16,700	March 16	12,150	April 16	10,620
February 7	8,250	March 17	39,800	April 17	8,864
February 8	4,500	March 18	36,550	April 23	8,777
February 9	3,145	March 19	23,200	April 24	11,500
February 15	2,867	March 20	44,400	April 25	12,750
February 16	4,040	March 21	23,440	April 26	12,500
February 17	21,550	March 22	11,940	April, 27	11,160
February 18	20,450	March 23	9,524	April 28	10,800
February 19	7,000	March 24	9,895	April 29	9,906
February 20	4,800	March 25	8,040	April 30	9,370
February 27	4,400	March 26	7,860		
February 28	27,550	March 27	7,480		

NOTE.—The daily discharge during May varied gradually from 9,350 to 1,950 second-feet.

The table shows one flood in January, three in February, four in March, and three in April. The largest of these floods occurred April 13. The rate of flow was 45,470 second-feet, or 7.9 second-feet per square mile; on March 20 the daily rate was 44,400 second-feet, nearly as large as on April 13. The highest stage during these four months at this station was 23.5 feet and the lowest 6.9 feet.

The following table gives the greatest daily rate of flow of Salt River at Roosevelt each year, from 1889 to 1905;

Maximum daily discharge, in second-feet, of Salt River at Roosevelt, Ariz., 1889–1905.[a]

[Drainage area, 5,756 square miles.]

Year.	Month.	Discharge.	Year.	Month.	Discharge.
1889....	March........................	18,930	1900...	November..................	2,220
1890....	February.....................	71,640	1901...	February..................	4,170
1891....	February.....................	150,000	1902...	August....................	4,680
1892....	October......................	770	1903...	April.....................	2,050
1894....	March........................	1,430	1904...	August....................	14,700
1895....	January......................	46,810	1905...	January...................	12,300
1896....	July.........................	5,530	1905...	February..................	27,550
1897....	January......................	10,420	1905...	March.....................	44,400
1898....	August.......................	1,210	1905...	April.....................	45,470
1899....	August.......................	3,330	1905...	November..................	97,710

[a] This station is described in Water-Supply Paper No. 100, p. 42.

According to these records, the greatest daily rate of flow during these seventeen years was nearly 26 second-feet per square mile in February, 1891.

The following table gives the maximum, minimum, and mean monthly run-off of the Salt and Verde rivers for January–April, 1905, and for the same months of 1891:

Comparison of floods of 1891 [a] *and 1905* [b] *on Salt River at Roosevelt and on Verde River at McDowell, Ariz.*

SALT RIVER AT ROOSEVELT.

[Measurements in second-feet.]

Date.	Maximum.		Minimum.		Mean.	
	1891.	1905.	1891.	1905.	1891.	1905.
January..................................	8,900	12,300	551	165	1,777	1,611
February.................................	150,000	27,550	413	526	19,408	8,207
March....................................	4,970	44,400	753	6,000	2,768	15,300
April....................................	2,180	45,470	1,654	6,495	1,922	12,550
Mean, January–April..............	....	....	....	....	6,467	9,417
Acre-feet, January–April..........	....	....	....	....	1,471,000	2,242,000

VERDE RIVER AT McDOWELL.

Date.	Maximum.		Minimum.		Mean.	
	1891.	1905.	1891.	1905.	1891.	1905.
January..................................	7,190	10,060	445	241	1,435	1,419
February.................................	135,000	32,970	371	499	17,467	7,709
March....................................	3,460	29,410	525	1,887	1,928	8,780
April....................................	606	32,140	459	1,411	534	5,227
Mean, January–April..............	....	....	....	....	5,341	5,784
Acre-feet, January–April..........	....	....	....	....	1,209,000	1,366,000

[a] Prepared from data Water Supply and Irrigation Paper No. 73, pp. 14 and 26.
[b] Discharge obtained by taking proportional part of discharge of Salt River at Arizona dam.

The maximum daily rate of flow of both Salt and Verde rivers was more than three times as great in February, 1891, as at any time during the period January–April, 1905, but the total flow of Salt River below the mouth of the Verde was 1.24 times greater during the period January–April, 1905, than during the same period of 1891.

VERDE RIVER.

The precipitation in the drainage basin of the Verde during the months January–April can be seen from the table on page 39. The daily rate of flow during these floods, as measured at the gaging station at McDowell, near the mouth of the river, is given in the following table:

Daily discharge, in second-feet, of Verde River at McDowell, Ariz., during floods, January to April, 1905.

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
January 9	285	February 22	4,311	March 20	10,630
January 10	8,674	February 23	5,610	March 21	9,368
January 11	10,060	February 24	12,170	March 22	8,110
January 12	7,394	February 25	6,126	March 23	6,853
January 13	2,379	February 26	4,572	March 24	5,594
January 14	1,400	February 27	4,650	March 25	5,070
January 15	1,100	February 28	21,050	March 26	4,755
January 16	860	March 1	25,130	March 27	3,916
January 17	755	March 2	10,580	March 28	3,077
January 18	1,100	March 3	8,800	March 29	2,770
January 19	944	March 4	8,107	March 30	2,158
February 2	507	March 5	7,414	March 31	1,887
February 3	968	March 6	5,928	April 10	1,493
February 4	32,970	March 7	5,276	April 11	6,433
February 5	32,970	March 8	4,884	April 12	32,140
February 6	19,310	March 9	3,946	April 13	24,640
February 7	9,743	March 10	3,289	April 14	15,160
February 8	5,400	March 11	2,617	April 15	13,720
February 9	3,750	March 12	2,539	April 16	10,710
February 15	1,403	March 13	7,612	April 17	7,566
February 16	1,367	March 14	25,500	April 18	5,471
February 17	4,950	March 15	10,580	April 19	3,639
February 18	9,767	March 16	10,780	April 20	2,337
February 19	8,641	March 17	29,410	April 21	1,893
February 20	6,130	March 18	23,460	April 22	1,617
February 21	5,004	March 19	12,120		

The greatest daily rate of flow during these four months at this place was about 33,000 second-feet, on February 4 and 5. The greatest daily rate per square mile during this period was 5.5 second-feet, and the stage varied from 1 foot to 13.25 feet.

The monthly and total run-off at this station for these four months were given on page 45.

The following table gives the greatest daily rate of flow of the Verde River near its mouth each year from 1889–1905:

Maximum daily discharge, in second-feet, of Verde River at McDowell, Ariz., 1889–1905.[a]

[Drainage area, 6,000 square miles.]

Year.	Month.	Discharge.	Year.	Month.	Discharge.
1889	March	13,180	1899	October	3,770
1890	February	64,480	1900	November	2,470
1891	February	135,000	1901	February	6,610
1894	March	996	1903	April	[b] 95,000
1895	January	33,000	1904	July	6,080
1896	August	5,320	1905	February	32,970
1897	January	15,690	1905	April	32,140
1898	July	1,890	1905	November	61,460

[a] This station is described in Water-Supply Paper No. 100, p. 31.
[b] Gage height, 19 feet. Discharge, upward of 95,000 second-feet.

According to these records the greatest daily rate of flow at this station during these seventeen years was about 23 second-feet per square mile in February, 1891.

GILA RIVER AT DOME, ARIZ.

The following table gives the daily discharge of the Gila at Dome (Gila City), Ariz., 15 miles from the mouth of the river, for January-May, 1905:

Daily discharge, in second-feet, of Gila River at Dome, Ariz., for period January-May, 1905.

Day.	January.	February.	March.	April.	May.
1	0	80	5,150	6,800	9,500
2	0	0	21,500	6,800	8,100
3	0	0	34,000	6,000	8,500
4	0	0	11,800	7,300	7,700
5	0	280	5,000	8,500	6,000
6	0	2,200	3,050	12,400	6,400
7	0	20,800	1,050	13,800	6,000
8	0	82,000	450	9,000	5,000
9	0	35,800	370	8,100	5,000
10	40	14,900	300	8,500	5,000
11	2,220	6,900	5,000	9,000	4,100
12	2,600	2,920	10,000	8,500	5,600
13	2,840	60	3,800	22,000	5,000
14	2,960	1,920	3,500	64,000	4,400
15	4,680	300	10,300	34,000	4,700
16	18,600	0	39,000	23,000	5,000
17	26,000	140	20,000	15,300	5,000
18	10,200	230	27,800	10,900	4,700
19	5,650	24,800	62,000	8,300	3,800
20	3,690	42,800	95,000	6,200	4,400
21	3,060	45,200	25,500	5,150	3,800
22	2,560	40,200	20,000	6,400	4,100
23	1,990	630	18,000	8,300	4,400
24	1,660	300	16,100	7,900	3,800
25	1,460	900	14,500	9,250	3,500
26	1,290	9,250	13,100	12,750	3,500
27	1,180	5,150	11,800	12,100	3,500
28	1,020	5,300	10,600	13,100	3,300
29	830	....	9,500	12,750	2,800
30	560	....	8,500	11,200	2,350
31	310	....	7,700	....	2,150
Total	95,400	343,080	514,370	387,300	151,100
Mean	3,077	12,250	16,590	12,910	4,874
Run-off, in acre-feet	189,200	680,300	1,020,000	768,200	299,700

The table shows one flood in January, two in February, two in March, and one large and two small ones in April. The greatest rate of flow was 95,000 second-feet, on March 20. The first flood in February is more characteristic of floods on this stream than any of the others. They are generally of short duration, the rise and fall being very rapid. The long-continued rains of this period gave a character to these floods not unlike that of streams in the eastern part of the country.

The total run-off for the five months is 2,957,400 acre-feet. To appreciate the magnitude of the run-off on this stream during this period it is necessary to remember that this stream is usually dry at this place about ten months of the year.

The stream at this place was about 4 feet higher during the great flood of February, 1891, than during this flood. The rate of flow of the river for a given gage height changes greatly at this station. On February 8, 1905, the rate was found to be 82,000 second-feet for a gage height of 16.95 feet; on March 20 it was found to be 95,000 second-feet for a gage height of 13.1 feet The bed is sandy and not only scours out during a flood and fills in after it, but the channel changes from one side of the bottom to the other. The width when the stream is flowing is generally not more than 100 feet, but during some of these floods the whole bottom was flooded; thousands of acres of land that were covered with arrowwood, mesquite, and cottonwood before the floods are now part of the river bed or bare mud flats. This continual changing of the river bed has made it exceedingly difficult to secure reliable estimates of the rate of flow, and some of the estimates may be largely in error.

The damage done by the floods along the lower Gila consisted mainly in washing away large areas of good land along the river, some of which was under cultivation.

SUMMARY.

The following table gives the monthly and total flow in acre-feet, January–April, 1905, at four of the gaging stations in this basin:

Monthly and total discharge, in second-feet, at stations in Gila River basin, January–April, 1905.

Stream.	Place.	January.	February.	March.	April.	Total.
San Francisco	Alma, N. Mex	17,340	43,870	79,260	72,830	213,300
Verde	McDowell, Ariz	87,250	428,100	539,900	311,000	1,366,000
Salt	Roosevelt, Ariz	99,060	455,800	940,800	746,800	2,242,000
Gila	Dome, Ariz	189,200	680,300	1,020,000	768,200	2,658,000

The flow at the Arizona dam is approximately the sum of the volumes of flow of the Salt at Roosevelt and the Verde at McDowell, which is 3,608,000 acre-feet. The total flow at this place is about 1.36 times the volume of flow for the same period at Dome, near the mouth of the Gila.

COLORADO RIVER AT YUMA, ARIZ.

The gaging station at Yuma is below the mouth of the Gila, and the records there show the combined flow of the Gila and upper Colorado. The Hardyville station is about 300 miles above Yuma. The only comparatively large stream entering between these stations is Williams River. Along the Colorado between these stations there are from 200,000 to 225,000 acres of lowlands subject to overflow during floods. Overflow of these lowlands begins at a gage height of about 24.5 feet,[a] Yuma gage. The Colorado reached a stage of 24.85 feet at Yuma (8 feet Hardyville gage) on May 23 and remained above 24.5 feet until July 5. These lowlands were therefore flooded for about forty-five days.

[a] Second Ann. Rept. U. S. Reclamation Service, p. 150.

The following table gives the daily rate of flow of the Colorado at Yuma from January 1 to July 31, 1905:

Daily discharge, in second-feet, of Colorado River at Yuma for the period January–July, 1905.

Day.	January.	February.	March.	April.	May.	June.	July.
1	3,750	5,800	29,070	20,690	41,520	61,500	57,800
2	3,750	6,054	39,260	20,100	39,700	65,300	55,500
3	3,800	6,500	70,170	19,480	39,700	68,160	50,640
4	3,985	6,632	70,200	19,450	37,280	67,900	45,000
5	4,300	9,800	51,100	21,000	37,100	67,600	44,950
6	4,570	16,560	44,310	30,100	37,410	67,600	42,400
7	4,700	9,400	44,100	29,840	38,000	69,500	40,100
8	4,500	62,080	43,100	25,800	40,050	72,930	37,200
9	4,170	82,820	36,400	24,800	46,000	70,300	35,500
10	16,090	52,580	34,400	24,900	49,200	69,600	32,980
11	6,400	37,320	38,620	23,000	52,000	71,000	32,100
12	6,300	29,700	42,000	26,100	48,000	72,590	31,720
13	6,350	22,800	38,870	45,800	38,840	76,000	30,870
14	7,000	21,900	32,000	93,800	37,800	82,020	29,500
15	8,370	22,500	36,720	97,500	37,300	82,000	27,710
16	8,600	18,610	60,640	70,100	37,320	83,000	28,300
17	20,100	14,600	65,820	45,000	37,000	86,000	31,100
18	27,500	16,490	62,400	43,600	33,910	88,500	25,300
19	19,300	31,500	73,440	45,050	34,200	94,320	22,320
20	12,120	47,000	110,800	43,400	34,580	91,500	22,250
21	9,300	54,200	103,500	39,500	35,700	92,400	22,000
22	10,170	54,730	91,200	35,900	37,000	92,400	21,500
23	7,863	32,990	76,930	33,900	38,400	89,800	20,900
24	7,900	21,990	58,600	31,690	41,500	84,800	20,800
25	7,025	18,850	43,050	33,000	43,700	82,000	20,650
26	6,770	30,500	34,600	37,160	45,300	77,610	20,460
27	6,250	27,730	31,020	41,630	47,600	73,500	19,700
28	5,730	25,000	29,500	39,000	51,100	68,500	18,910
29	5,400	....	26,900	35,000	54,810	64,370	17,200
30	5,070	....	24,390	38,700	56,300	61,500	17,500
31	4,900	....	23,500	59,020	59,020	....	16,750
Mean run-off	8,130	28,100	50,540	37,830	42,170	76,470	30,310
Per square mile	0.0361	0.125	0.225	0.168	0.187	0.340	0.135
Depth in inches	0.042	0.130	0.259	0.187	0.216	0.379	0.156
Acre-feet	499,900	1,561,000	3,108,000	2,251,000	2,593,000	4,550,000	1,864,000

There were two flood periods in January—one that reached a rate of 16,090 second-feet on the 10th and one that reached a rate of 27,500 second-feet on the 18th; two floods in February—one that reached a rate of 82,800 second-feet on the 9th and one that reached a rate of 54,730 second-feet on the 21st; two floods in March—one that reached a rate of 70,170 second-feet on the 4th and one that reached a rate of 110,800 second-feet on the 20th; one in April, that reached a rate of 97,500 second-feet; one in May, with a rate of 52,000 second-feet; and one in July, with a maximum rate of 94,300 second-feet. The flood in July came from the upper Colorado; all the others came from the Gila, as can be seen from the records at Dome and Hardyville. The daily flow at this station for this period is shown on fig. 8. The highest stage of water at the Yuma gage during these floods was 30.3 feet, on March 20, when the rate of flow was 110,800 second-feet or 0.49 second-foot per square mile. The highest stage of water at the Yuma gage during the great flood on the Gila in 1891 was 33.2 feet. The greatest flow from the Colorado above Yuma was 92,400 second-feet, on June 21.

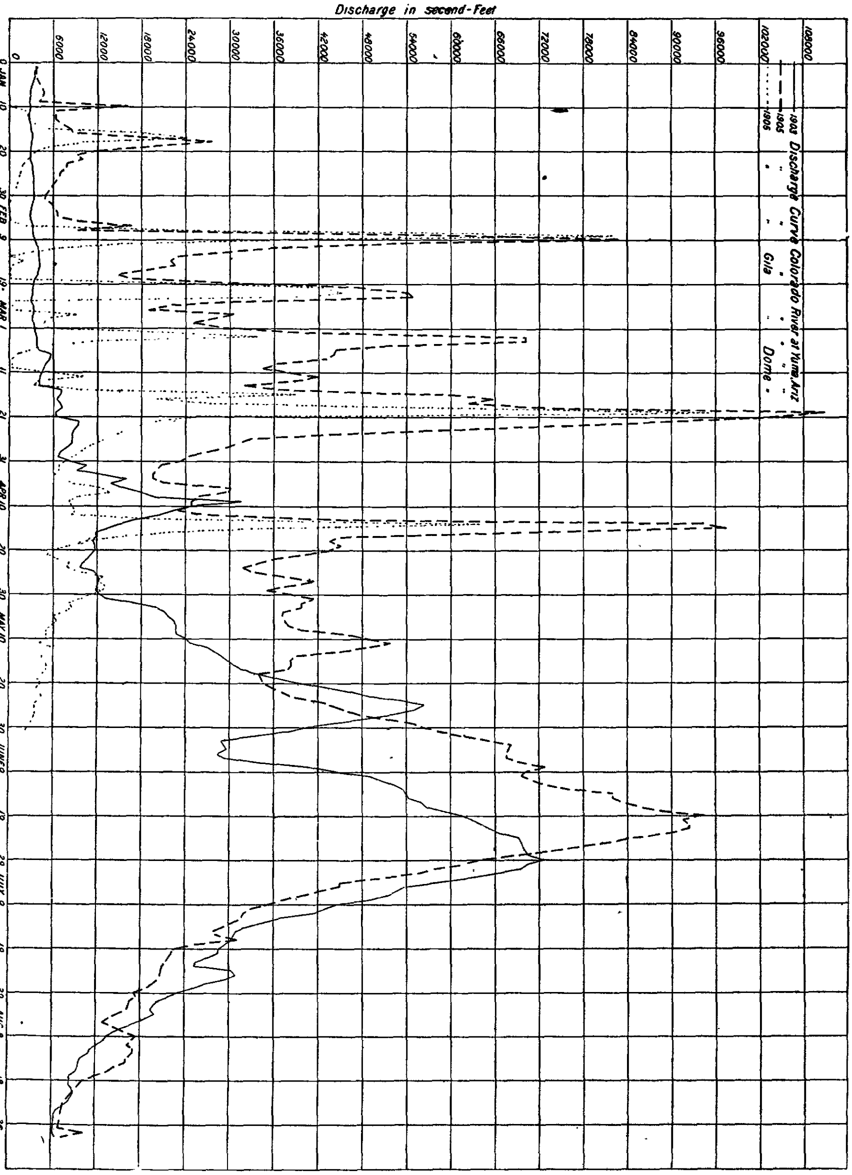


FIG. 8.—Diagram showing flood flow of Colorado and Gila rivers.

The flood of 1903 on the Colorado above Yuma is regarded as one of the largest recorded to that date. In the following table the monthly run-off, in acre-feet, during the floods of 1903 and 1905 are compared.

The following table gives a comparison of run-off in acre-feet of Colorado River at Yuma during the floods of 1903 and 1905:

Flow of Colorado River at Yuma, Ariz., in acre-feet, during floods of 1903 and 1905.

Month.	1903.	1905.	Month.	1903.	1905.
January	189,935	499,900	June	3,162,526	4,550,000
February	187,271	1,561,000	July	2,304,494	1,864,000
March	376,120	3,108,000	Total	9,147,086	16,426,900
April	852,456	2,251,000			
May	2,074,284	2,593,000			

The run-off for these seven months was 1.8 times greater in 1905 than in 1903.

The following table gives the greatest daily rate of flow at this station each year from 1894 to 1905:

Maximum daily rate of flow, in second-feet, of Colorado River at Yuma, Ariz., 1894-1905.[a]

Year.[b]	Date.	Discharge.	Year.	Date.	Discharge.
1894	June 15	34,700	1903	June 28	72,219
1895	May 23	35,550	1904	June 7	51,170
1896	June 9	38,100	1905	February 9	82,820
1897	do	55,300	1905	March 20	110,800
1898	June 27	33,100	1905	April 15	97,500
1899	June 29	52,700	1905	May 31	59,000
1900	June 10	54,400	1905	June 19	94,320
1901	July 1	63,450	1905	November 30	102,700
1902	May 26	59,200			

[a] This station is described in Water-Supply and Irrigation Paper No. 133, p. 25.
[b] Discharge prior to 1902 was obtained from the station rating curve of 1902.

The valley immediately above and below Yuma contains about 100,000 acres of irrigable land, and about 75,000 acres were covered by these floods. The damage done by the floods in the Yuma Valley proper—that portion on the east side of the river below Yuma—was estimated as follows:

Damage done in Yuma Valley by flood on Colorado River in 1905.

Crops	$50,000
Ditches, small levees land along the river, etc	10,000
Buildings	10,000
Canals	10,000
Total	80,000

The town of Yuma is well protected by levees, built by the Government after the great flood of the Gila in 1901.

FLOOD IN GILA BASIN, NOVEMBER, 1905.

There was a short but very large flood in the Gila from November 27 to December 2. The rate of flow and damage done far exceeded that during the spring floods.

PRECIPITATION.

The precipitation for the month of November in Arizona, as determined by the United States Weather Bureau at 56 stations, was nearly 4 inches above the average for November. There were three wet periods, one from the 4th to the 9th, a second from the 20th to the 23d, and the third from the 26th to the 28th. It was the rain of the third period that caused the flood. The daily precipitation from the 26th to the 28th and the total precipitation for the month are given in the following table for 26 places in the Gila and Little Colorado drainage basins:

Daily precipitation in Gila and Little Colorado River basins November 26–28, 1905, in inches.

Place.	November.			Sum.	Month of November.
	26.	27.	28.		
Jerome, Ariz	1.00	2.20	0.50	3.70	8.80
Prescott, Ariz	1.62	1.90	.61	4.13	8.68
Seligman, Ariz	.82	.61	....	1.43	4.83
Alma, N. Mex	....	1.10	....	1.10	5.70
Young, Ariz	2.10	1.16	....	3.26	8.36
Alpine, Ariz	.83	.26	....	1.09	6.30
Fort Apache, Ariz	1.45	.45	Tr.	1.90	4.64
Phoenix, Ariz	1.02	.49	....	1.51	3.61
Deming, N. Mex	.68	.01	....	.69	2.72
Fort Bayard, N. Mex	1.30	Tr.	....	1.30	3.66
San Carlos, Ariz	1.40	.20	....	1.60	4.04
Cambray, N. Mex	....	1.00	....	1.00	1.50
Dudleyville, Ariz	.80	.85	.62	2.27	5.65
Lordsburg, N. Mex	....	.61	....	.61	2.93
Mesa, Ariz	1.24	.14	....	1.38	3.55
Luna, N. Mex	1.05	.06	Tr.	1.11	6.01
Buckeye, Ariz	1.10	1.02	.02	2.14	5.01
Maricopa, Ariz	.89	.58	.18	1.65	3.47
Yuma, Ariz	1.14	....	....	1.14	2.44
Roosevelt, Ariz	Tr.	2.16	.46	2.62	5.21
Benson, Ariz	.32	....	....	.32	3.08
Duncan, Ariz	.85	.05	.05	.95	2.90
Holbrook, Ariz	1.01	.10	....	1.11	3.82
Kingman, Ariz	.48	.55	....	1.03	1.86
Flagstaff, Ariz	.98	1.74	.60	3.32	7.00
Tuba, Ariz	.12	.76	.06	.94	2.32

It can be seen from the above table that the precipitation at the headwaters of Gila, Salt, and Verde rivers was from 2 to 4 inches for the three days, November 26–28.

FLOW.

The following table gives the daily rate of flow of Colorado River at Yuma, Gila River at Dome and Cliff, the Salt at Roosevelt, and the Verde at McDowell during this flood:

Daily discharge, in second-feet, of Colorado, Gila, Salt, and Verde rivers during flood of November and December, 1905.

Date.	Colorado River at Yuma, Ariz.	Gila River at Dome, Ariz.[a]	Gila River at Cliff, N. Mex.	Salt River at Roosevelt, Ariz.	Verde River at McDowell, Colo.
November 26	6,580	180	419	2,150	1,610
November 27	6,650	480	13,640	97,710	61,460
November 28	24,500	780	9,835	45,250	13,120
November 29	62,500	95,000	6,700	14,050	5,520
November 30	102,700	36,900	4,515	9,480	4,240
December 1	77,360	30,700	3,190	8,700	3,280
December 2	37,160	24,400	2,387	4,700	2,400
December 3	40,200	18,200			
December 4	35,000	11,900			
December 5	28,650	5,700			
December 6	23,300	5,000			

[a] The stream was dry at this place from July 20 to September 13, and from October 19 to November 13, 1905.

NOTE.—Highest stage at Yuma, January-April, 1905, was 30.3 feet on March 20.

The greatest daily rate of flow of the Colorado at Yuma during this flood was 102,700 second-feet, only about 8,000 second-feet less than the daily rate on March 20, 1905.

The flow of the Gila at Dome reached a daily rate on November 26 of about 95,000 second-feet, the same as on March 20, 1905, and the same as the greatest daily rate during spring floods on this stream.

The flow of Salt River at Roosevelt reached a daily rate of 97,710 second-feet on the 27th, which is more than twice as great as the greatest rate of flow at this place during the spring floods of 1905. The water at this place rose to a stage of 35.8 feet—that is, 13 feet above that on April 13, 1905, when the rate of flow was the greatest during the spring floods. The mean daily stage on November 27 was 26.7 feet—that is, about 9 feet less than the maximum stage for that day. The maximum rate of flow on the morning of the 27th is estimated to have been 148,000 second-feet.

The greatest daily rate of flow of the Verde at McDowell was 61,460 second-feet on November 27, which is nearly twice as great as the greatest daily rate reached during the spring floods of 1905.

In places where the canyon was narrow the water rose to a height of 40 feet above low water. Verde and Tonto rivers reached a maximum stage earlier than Salt River, hence the Salt at Phoenix was not so high as in February, 1891, but indications seem to show that Salt River above the mouth of the Tonto was higher during this flood than at any time during its history.

DAMAGE.

The damage done by this flood on Salt River was very great. The bridges of the Gila Valley, Globe and Northern Railway and the Maricopa, Phoenix and Salt River Valley Railway across Gila River were swept away. The old Southern Pacific Railway bridge and the new Santa Fe Railway bridge across Salt River near Tempe and the approaches of the new Southern Pacific Railway bridge at Tempe were damaged. The Arizona dam and all other dams on Salt River were swept away. The water rose above the top of the head gates of the canal and greatly damaged the banks where the water passed back into the river. The river rose 4 feet above the bridge at the gaging station at Roosevelt and swept it away. The flume and the cofferdam of the Roosevelt dam were swept completely away, and the Phoenix-Roosevelt road through the canyon below the dam was badly damaged.

FLOOD ON LITTLE COLORADO RIVER IN NOVEMBER.

The excessive precipitation in the basin of the Little Colorado River November 26–28 (see p. 52) produced a sudden and large increase in the flow of this stream. The daily gage height and rate of flow at the gaging stations at Woodruff and Holbrook, Ariz., are given in the following table:

Flood flow of Little Colorado River at Woodruff and Holbrook, Ariz., November 26–30, 1905.

Date.	Woodruff, Ariz.		Holbrook, Ariz.	
	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
November 26	1.00	33	3.50	160
November 27	21.90	10,000	8.55	20,180
November 28	7.75	2,960	5.75	7,295
November 29	5.50	1,735	4.05	1,000
November 30	2.00	85	3.80	260

It is seen that the stage at Woodruff rose from 1 foot on the 26th to 21.9 feet on the 27th and the rate of flow from 33 second-feet to 10,000 second-feet.

At Holbrook the rate of flow increased from 160 second-feet to 20,180 second-feet in twenty-four hours.

FLOW OF COLORADO RIVER INTO SALTON SINK.

Salton Sink is a body of water in the southern part of California about 90 miles northwest of Yuma. It is noted for the fact that its surface is about 290 feet below sea level. Imperial Valley, in which it is located, has a length of about 90 miles and an area below sea level of about 1,000,000 acres. Much of the soil of this valley is very productive, and in order to irrigate it a channel was excavated from Colorado River to Alamo River, an old channel leading into the valley from a point just north of the California-Mexico boundary line, 10 miles below Yuma. This canal, which passes through material that is easily eroded, was left without head gates. It had a low grade and dredging was necessary to keep it open. In October, 1904, a cut-off channel 50 feet wide and 8 feet deep was excavated in Mexico from the river to the canal to procure a larger volume of water for irrigation. The floods from January to April, 1905, scoured the canal to some extent; the flood of May and June from the upper Colorado scoured it from a width of 100 feet to a width of 300 to 400 feet. As the latter flood subsided silt was deposited in the river channel below the canal headings and gradually closed the river channel.

The average fall of the Colorado from Yuma to the Gulf of California is about 1.25 feet per mile, and the average fall from the Colorado River to Salton Sink is about 3 feet per mile; and as the canal passes through material that is easily eroded, cutting of bed and banks took place rapidly. On June 30, 1905, 22 per cent of the river flow was passing into the canal. On July 8, 67 per cent passed into the canal, and October 25 the whole flow passed into the canal. In November an effort was made to turn the river away from the canal by constructing a diversion dam of brush, piles, and gravel, but the sudden large November flood (p. 53) swept away the dam and greatly widened and deepened the cut-off canal. An attempt was also made to divert the flow of the Alamo canal back into the gulf by a short channel to Padrone River, which flows into Volcano Lake. A dam was built across New River at the lower end of this lake to force the lake to discharge to the southeast, into the gulf, instead of through New River into Salton Sink. Padrone River, however, cut a new channel across the country to New River, and thus the water passed into the sink instead of into the gulf. Near the close of 1905 the water in the sink was described as 45 miles long, from 10 to 18 miles wide, and 23.5 feet in greatest depth. It is reported that the water in the sink rose at the rate of one-half to three-fourths of an inch a day and during the larger floods at the rate of 2 inches a day.

The works of the New Liverpool Salt Company, located on the shores of the sink, have been drowned out. At the close of 1905 the water was up to the roofs of the buildings. The Southern Pacific Railway has 60 miles of main line and 40 miles of branch lines in this valley below sea level. Up to February, 1906, 40 miles of new track had been laid by this company 50 feet above the old location. It is said that $25,000 were spent on the construction of the diversion dam at the entrance to the canal that was swept away by the November flood.

The most serious danger to this valley is that before the river is controlled the canal may be cut so deep that water can not be taken from it to the irrigable land by gravity.

UNUSUAL RATES OF RUN-OFF IN 1905.

The following unusual rates of run-off occurred in the United States in 1905:

Extraordinary rates of run-off in 1905.

Stream and place.	Drainage area.	Date.	Maximum rate.
	Sq. miles.		*Sec.-feet.*
Mill Brook near Edmeston, N. Y.	9.4	September 3-4	241
Mad Brook near Sherburne, N. Y.	5.0	September 3-4	262
Starch Factory Creek near Utica, N. Y.	3.4	September 3	209
Do	3.4	June 21	190
Six-Mile Creek near Ithaca, N. Y.	46.0	June 21	195

FLOOD DISCHARGE AND FREQUENCY IN THE UNITED STATES.

INTRODUCTION.

Water-Supply Paper No. 147, "Destructive floods in the United States in 1904," pages 184–189, gives the greatest rate of flow of the largest recorded flood on many streams in this country. The following pages contain data on the daily rate of flow and frequency of all the larger floods on some streams. These streams are selected in preference to others on account of the long record of flood observation on them. The periods over which the flood records extend vary from eleven to more than one hundred years. The source of information is given in each compilation; when no statement to the contrary is made, the data were obtained by engineers and hydrographers of the United States Geological Survey.

A brief description of each drainage basin is given, especially of the part above the gaging station where the data were obtained, with a statement of the features that influence flood flow. Brief notes calling attention to the more important facts shown by the data are also presented.

At flood flow a stream usually carries much drift, overflows its banks, and changes height rapidly, so that it is very difficult to measure accurately its discharge at maximum stage. Some of the data here given are computed from careful measurements made during or shortly after the flood and some are computed from a single station rating curve, assuming the channel conditions to have been fairly constant during the period considered.

Primarily the flood flow of a stream depends on—

(1) The extent, duration, and intensity of precipitation, especially the intensity in the case of small drainage basins.

(2) The direction of motion of the storm causing the flood. If the storm moves in the direction of the flow of the stream the flow will be greater than if it moves in the opposite direction or across it.

(3) The amount of snow on the ground and the temperature during the storm. The large floods on northern streams are due almost entirely to the rapid melting of snow. When the ground is frozen the measured run-off is occasionally more than three times the precipitation during the month.

(4) The storage, both natural and artificial, in the drainage basin. In some basins ground storage may take up 9 inches of precipitation. Storage extends the flood period and reduces the maximum rate of flow.

(5) The size of the drainage basin. Most great rainstorms cover comparatively small areas, so that a big storm is likely to cover a larger part of a small drainage basin than of a large one. The maximum rate of discharge per square mile will therefore increase as the size of the drainage basin decreases.

(6) The physiography of the drainage basin. The maximum rate of flow from a comparatively long and narrow basin with tributaries entering a considerable distance apart will be less than from a basin of nearly circular shape of the same size but with tributaries entering the main stream in close proximity. Steep, impervious, deforested slopes of basin and steep slope of stream bed cause rapid run-off. Narrow, deep, crooked channels of small slope cause sluggish flow, great variations in stage, and frequent overflow.

Among the more or less artificial conditions that increase the flow may be mentioned—(1) controlled storage; (2) deforestation and cultivation; (3) reduction in width of channel by placing the abutments of bridges in the stream; (4) the use of piers that prevent scour of bed, collect drift, and hold back a part of the flow for a time, causing greatly increased flood wave; (5) the formation of ice gorges and the failure of dams and reservoir walls.

KENNEBEC RIVER.

Kennebec River is the outlet of Moosehead Lake, in northwestern Maine. The basin has a length of 150 miles, a width of 50 to 80 miles, and an area of 6,330 square miles. Its upper part is mountainous and thickly forested; its lower part is hilly or gently rolling, with grass-covered slopes. In this basin are 360 square miles of lake storage, controlled mainly by dams at the outlet of each lake. This stored water is used principally for log driving. From Moosehead Lake to Augusta, the head of navigation, a distance of 112 miles, the stream has an average fall of 9.1 feet per mile.

The following table gives the daily rate of flow of this stream at the Hollingsworth & Whitney Company's dam at Waterville, Me., during the greatest annual floods, from 1893 to 1904.

Flood flow of Kennebec River at Waterville, Me., from 1893 to 1904.

[Drainage area above this gaging station, 4,380 square miles.]

Year.	Date.	Discharge.[a]	Year.	Date.	Discharge.[a]
		Sec.-feet.			*Sec.-feet.*
1893	May 18	83,500	1898	April 15	50,380
1894	April 23	35,280	1899	April 27	45,800
1895	April 15	86,200	1900	April 21	62,290
1896	March 1	6,260	1901	April 9	76,600
1896	March 2	111,200	1902	March 4	54,340
1896	March 3	52,690	1903	March 20	35,700
1896	March 4	24,810	1904	May 12	37,840
1897	April 8	66,900			

[a] Data furnished by Hollingsworth & Whitney Company.

The largest flood in these fifteen years at Waterville occurred on March 2, 1896, when the rate of flow for the day was 111,200 second-feet, or 25.2 second-feet per square mile. The rise was exceedingly rapid, the discharge increasing from about 6,000 to 111,000 second-feet in twenty-four hours.

The greatest flood in the upper part of this basin occurred on December 15, 1901. At 8 a. m. only a few second-feet of water were flowing over the dam at Madison, Me., where the drainage area is 2,850 square miles. At midnight the depth of water on the crest of this dam was 14.5 feet and the rate of flow was 105,000 second-feet. At 9 a. m. the next day the water surface had fallen 5.5 feet.

The large floods in this basin all occur in the spring or winter and are due to rain and the rapid melting of the winter accumulations of snow. The summer floods are small compared with the spring floods.

ANDROSCOGGIN RIVER.

The Androscoggin is the outlet of the Umbagog-Rangeley lakes in western Maine. The basin has a length of about 110 miles, a greatest breadth of 70 miles, and an area of 3,700 square miles. The upper part of the basin is mountainous, broken, and thickly forested; the lower part is hilly, with grass-covered or cultivated slopes. There are 148 lakes in the basin, having a water-surface area of 312 square miles—that is, about one-twelfth of the basin is water surface. From the foot of Umbagog Lake to the foot of Rumford Falls, a distance of 81 miles, the stream falls 836 feet. The lakes are largely controlled by dams and the storage is used mainly for log driving. The range of stage at Lewiston near the mouth is 8 feet; at Bethel, 28 feet.

The following table gives the daily rate of flow of this stream at Rumford Falls, Me., during the greatest annual floods, from 1893 to 1903:

Flood flow of Androscoggin River at Rumford Falls, Me., from 1893 to 1903.

[Drainage area above gaging station, 2,320 square miles.]

Year.	Date.	Discharge.[a]	Year.	Date.	Discharge.[a]
		Sec.-feet.			*Sec.-feet.*
1893	May 18	38,060	1899	May 2	24,080
1894	April 21	22,230	1900	May 20	24,530
1895	April 22	55,230	1901	April 22	32,650
1896	April 17	27,390	1902	March 30	18,490
1897	July 15	22,900	1903	June 13	26,790
1898	April 25	16,750			

[a] Data furnished by C. A. Mixer, C. E., resident engineer of the Rumford Falls Power Company.

The greatest flood on this stream at this place in these twelve years occurred April 22, 1895. The greatest daily rate of flow was 55,230 second-feet, or 23.8 second-feet per square mile.

The larger floods in this basin occur in the spring and are due to rain and the rapid melting of snow. As a rule, the floods on this river are somewhat less in magnitude than those on the Kennebec.

MERRIMAC RIVER.

The Merrimac is formed by the union of the Pemigewasset and the Winnepesaukee rivers at Franklin, N. H. The basin is comparatively long and narrow and has an area of 4,916 square miles. The upper part is mountainous, broken, and forested; the central part is hilly or gently rolling, cultivated and pasture lands; the lower part is flat, with some swamps. There are in this basin more than 100 square miles of controlled storage. From its head at Franklin Junction to its mouth, a distance of 110 miles, the river falls 269 feet.

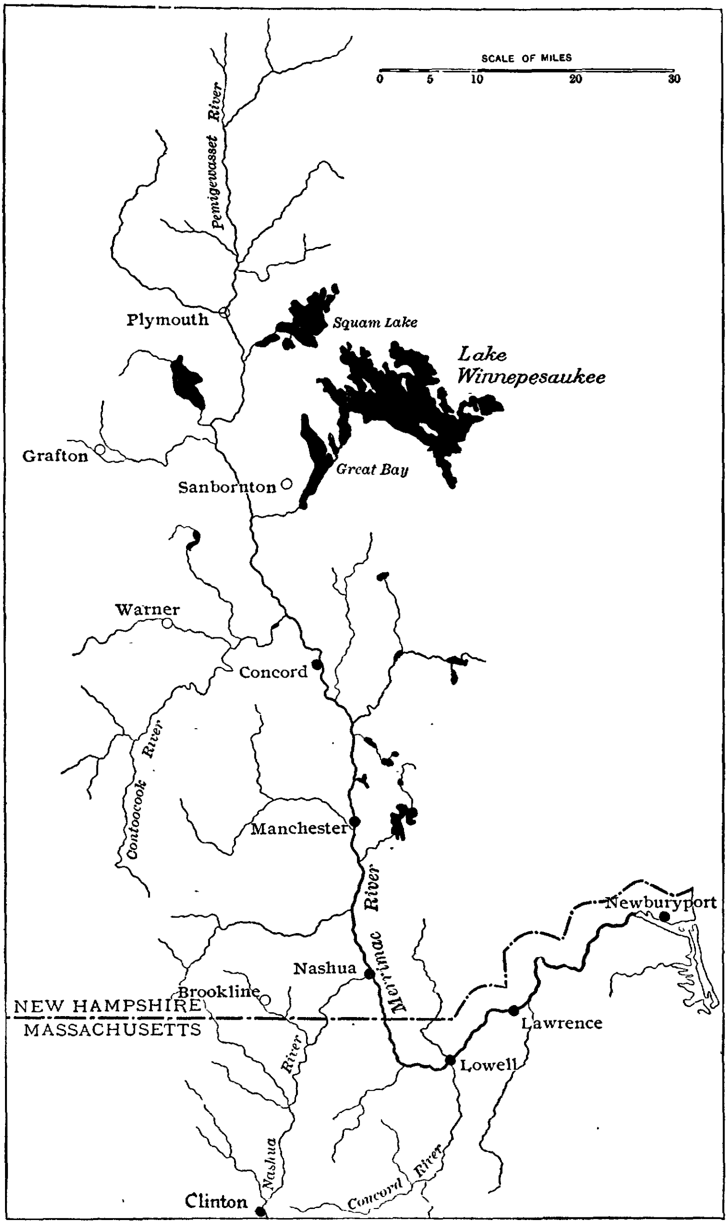


FIG. 9.—Map of drainage basin of Merrimac River.

A large part of this total fall is concentrated at six places. Along the stream are extensive tracts of bottom land, which are subject to overflow during floods, The following table gives the daily rate of flow and dates of occurrence of the larger floods since 1846 at Lawrence, Mass.:

Flood flow of Merrimac River at Lawrence, Mass., 1846 to 1904. [a]

[Drainage area, 4,553 square miles.]

Year.	Date.	Discharge.[a]	Year.	Date.	Discharge.[a]
		Sec.-feet.			*Sec.-feet.*
1846	Spring [b]		1900	February 15	52,990
1852	Spring [c]		1901	April 7	33,950
1890	October	31,450	1901	April 8	61,200
1892	May	32,800	1901	April 9	62,510
1893	May	44,800	1901	April 10	48,760
1894	March	27,900	1901	April 11	38,020
1895	April	65,300	1901	April 12	31,460
1896	March	82,150	1902	March 4	61,190
1897	July	41,500	1903	March 13	45,470
1898	March 15	36,000	1904	May 1	46,340
1899	April 17	38,200			

[a] Data furnished by R. A. Hale, engineer, Essex Water Power Company.
[b] Largest flood in recollection of inhabitants.
[c] Stage was 0.8 foot lower than in 1896.

The greatest flood since 1846 occurred March, 1896. On March 3 the stage at Lawrence was 25 feet above low water, and the maximum rate was 82,150 second-feet, or 18 second-feet per square mile. This was the spring flood and was largely due to rapid melting of snow. The floods due to rain alone are scarcely half the magnitude of the spring floods. The spring floods generally last from one to two weeks.

CONNECTICUT RIVER.

Connecticut River has its source in Connecticut Lake in northern New Hampshire. It falls from an elevation of 1,618 feet to nearly sea level at Hartford in a distance of about 312 miles. The basin, shown in fig. 10, is long and narrow and has an area of 10,924 square miles. The upper part is mountainous, with some forest area; the middle and lower

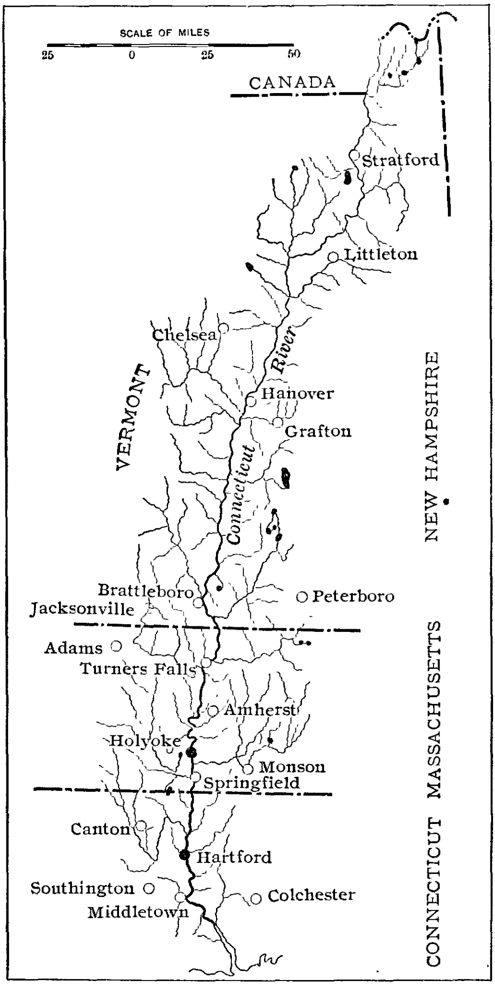


FIG. 10.—Map of drainage basin of Connecticut River.

parts are hilly or rolling—grass covered or cultivated. The river receives the water of many small tributaries and a small amount from lake storage. Above Bellows Falls the stream has numerous shoals and rapids; below this place its descent is much slower and is broken by rapids at only three places.

The following table gives the daily rate of flow and date of occurrence of the large floods on this stream at Hartford, Conn., since 1801:

Flood flow of Connecticut River at Hartford, Conn., 1801–1904.

[Drainage area, 10,234 square miles. Danger line, 13 feet gage height.]

Year.	Month.	Gage height.[a]	Discharge.[b]	Year.	Month.	Gage height.[a]	Discharge.[b]
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1801..	....	27.5	178,400	1878.	December............	23.9	138,200
1841..	....	26.3	164,700	1879.	May..................	21.4	113,500
1843..	....	27.2	175,000	1884.	April.................	21.5	114,400
1847..	April..................	21.0	109,800	1886.	May..................	21.8	117,200
1850..	May....................	20.8	108,100	1887.	April.................	22.5	124,000
1852..	April..................	23.1	129,800	1888.	April.................	19.4	96,060
1853..	November............	20.5	105,400	1889.	November 30..........	15.6	68,140
1854..	May....................	29.8	205,200	1890.	October 26............	16.0	70,700
1856..	August................	23.3	131,900	1891.	April 17...............	19.8	99,420
1859..	March.................	26.4	165,900	1892.	June 16...............	18.3	87,100
1861..	April..................	21.5	114,400	1893.	May 6.................	24.0	139,200
1862..	April..................	28.7	192,300	1894.	April 25...............	13.8	....
1865..	March.................	24.8	147,800	1895.	April 16...............	25.7	157,900
1866..	February.............	20.5	105,400	1896.	March 3..............	26.5	167,000
1867..	April..................	20.0	101,100	1897.	July 16................	20.8	108,100
1868..	March.................	21.5	114,400	1898.	March 22.............	21.2	110,700
1869..	April..................	26.7	169,300	1899.	April 27...............	[c]22.0	119,100
1869..	October...............	26.3	164,700	1900.	February 15..........	23.4	133,000
1870..	February.............	21.3	112,600	1900.	April 22...............	22.8	126.900
1870..	April..................	25.3	153,400	1901.	April 25..	22.7	125,900
1873..	April..................	21.0	109,800	1902.	March 4...............	25.5	155,600
1874..	January..............	23.9	138,200	1903.	March 25..............	23.4	133,000
1876..	April..................	21.9	118,200	1904.	April 30...............	21.4	113,500
1877..	March.................	22.9	127,800	1905.	March 31..............	22.8	126,900

[a] Furnished by Edwin Dwight Gravus, chief engineer Connecticut River bridge and highway district.
[b] Computed from rating table prepared by T. G. Ellis, C. E., Report Chief of Engineers U. S. Army, 1875, pt. 2, p. 364.
[c] From April 16 to April 31 the stage did not fall below 20 feet.

The flood of May, 1854, was the largest in more than a century, and reached a stage of 29.8 feet above low water at Hartford, Conn. The daily rate was 205,460 second-feet, or 20 second-feet per square mile.

The flood of April, 1862, was the largest at Holyoke, Mass., and gave a discharge of 162,000 second-feet, or 18.7 second-feet per square mile.

The largest flood that was due entirely to rain occurred in October, 1869. The maximum daily rate of flow was 16.5 second-feet per square mile. High stages in the spring sometimes last for two or more weeks.

HUDSON RIVER.

The drainage basin of Hudson River above the gaging station at Mechanicsville, N. Y., comprises 4,500 square miles. It is mountainous, with considerable lake storage and forest area.

Serious flood conditions exist in a stretch of the river extending for 30 miles below Albany. Here the channel is shallow, narrow, and crooked, and there is a tidal action and a large inflow from the Mohawk. The tidal action prevents the rapid passing out of ice, and aids in the formation of ice dams. Floods due to ice come with but little warning at any time from December to April.

The following table gives the rate of flow and date of occurrence of each of the large floods at Mechanicsville, N. Y., since 1869:

Flood flow of Hudson River at Mechanicsville, N. Y., 1869-1904.[a]

[Drainage area, 4,500 square miles. Danger line, 9.0 feet gage height.]

Year.	Date.	Discharge	Year.	Date.	Discharge.
		Sec.-feet.[b]			*Sec.-feet.*
1869....	Spring........................	70,000	1902...	March 3........................	41,360
1896....	April 18........................	42,620	1903...	March 23........................	42,910
1896....	November 7..................	24,550	1903...	March 24........................	54,490
1898....	March 14......................	39,230	1903...	March 25........................	56,280
1899....	April 26........................	41,480	1903...	March 26........................	50,640
1900....	April 23........................	43,550	1903...	March 27........................	41,580
1901....	April 23........................	54,860	1903...	March 28........................	32,930

[a] Data furnished by the Duncan Company, R. P. Bloss, engineer.
[b] Hydrology of the State of New York, 1905, p. 467.

The largest flood in these thirty-five years was in the spring of 1869, when the discharge was 70,000 second-feet, or 15.6 second-feet per square mile. The large floods all occur in the spring, and are due to rapid melting of the winter accumulation of snow with rain.

GENESEE RIVER.

Genesee River rises in northern Pennsylvania, flows northward across New York State, and empties into Lake Ontario. Its basin is 108 miles long, 22 miles wide, and comprises 2,400 square miles. The catchment area above Mount Morris has steep slopes with heavy and impervious soil and little wooded area. In the catchment area below Mount Morris there are from 60 to 80 square miles of flats subject to overflow. These flats act as a reservoir, decreasing to a marked degree the maximum rate of flow at Rochester. Near Portage the river passes through a narrow canyon and has a fall of 330 feet, nearly all of which is at Portage Falls.

The following table gives the daily rate of flow of this stream at Rochester, N. Y., of the large floods from 1785 to 1904, and the date of occurrence of each:

Flood flow of Genesee River at Rochester, N. Y., 1785-1904.[a]

[Drainage area, 2,428 square miles.]

Year.	Date.	Place.	Discharge.	Year.	Date.	Place.	Discharge.
			Second-feet.				*Second-feet.*
1785..	....	Rochester.....	40,000	1894.	May 18....	Mount Morris..	600
1835..	October...	Rochester.....	36,000	1894.	May 19....	Mount Morris..	5,530
1857..	February.	Rochester.....	30,000-35,000	1894.	May 20....	Mount Morris..	16,580
1865..	March....	Rochester.....	45,000-54,000	1894.	May 21....	Mount Morris..	42,000
1867..	February.	Rochester.....	20,000-25,000	1894.	May 22....	Mount Morris..	33,000
1873..	March....	Rochester.....	30,000-35,000	1894.	May 23....	Mount Morris..	15,650
1875..	March....	Rochester.....	30,000-35,000	1894.	May 24....	Mount Morris..	7,300
1879..	March....	Rochester.....	20,000	1896.	April.....	Rochester.....	33,000-36,000
1889..	June.....	Rochester.....	20,000	1902.	March....	Rochester.....	35,000-38,000
1890..	September	Mount Morris.	20,000	1902.	July......	Portage.......	40,000-50,000
1893..	March....	Mount Morris.	30,000	1903.	April 5....	Rochester.....	18,380

[a]Report of special committee on flood conditions in the Genesee River affecting the city of Rochester, N. Y., 1904.

The greatest rate of flow during this period at Rochester was during the flood of March, 1865, when the rate per square mile of drainage was 19 to 22 second-feet. This was a spring flood and was due largely to the rapid melting of snow.

The flood of May, 1894, which gave a maximum rate at Mount Morris of 42,000 second-feet, gave a maximum rate of only 20,000 to 21,000 second-feet at Rochester.

The flood of July 5-9, 1902, was without precedent in the high stage of water for the time of year and the damage done. The ground was saturated at the time. The precipitation for June and July was more than 12 inches over half of New York State and 18 inches at some stations in this basin.

PASSAIC RIVER.

The topography of this watershed has a marked effect on the flood flow of the stream and on the damage resulting from overflows. The watershed is fan shaped, consisting of a large central basin with a narrow outlet. The length of the stream from source to mouth is only 27 miles, but the length by river is 83. The total drainage area is 949 square miles, the area above Little Falls, the outlet of the central basin, is 772.9 square miles. All the important tributaries except one drain highland areas having steep, nearly impervious slopes and empty into the central basin. This basin is 8 to 12 miles wide, 32 miles long, and contains 29,300 acres. Much of it is marshy or wet land, flooded during ordinary freshets. As the outlet of this basin is too small to allow free flow from it, the water is held back for a time and the duration of each flood is increased.

The fall from this outlet to the ocean is mainly concentrated at three places, leaving little fall between. The channel cross section in part of the lower reach is also small.

The following table gives the daily rate of the flow of this stream at Dundee dam during the large floods from 1877 to 1903 and the date of occurrence of each:

Flood flow of Passaic River at Dundee dam, New Jersey, 1877-1903.

[Drainage area, 822.7 square miles.]

Year.	Date.	Maximum discharge.	Duration in hours.	Year.	Date.	Maximum discharge.	Duration in hours.
		Sec.-feet.				*Sec.-feet.*	
1877	March 29	10,780	60	1889	April 29	10,970	66
1878	September 12	16,590	60	1891	January 24	11,700	60
1882	September 25	18,260	60	1893	March 14	11,220	69
1886	February 14	12,450	60	1893	March 6	11,160	72
1886	April 8	10,420	55	1902	March 2	24,800	270
1888	February 3	11,880	68	1903	October 10	35,000	225
1888	September 21	11,130	72				

NOTE.—Records for years preceding 1902 are from Report Geol. Survey, New Jersey, 1894, vol. 3. p. 53; records for 1902 and 1903 are from Water-Supply and Irrigation Paper U. S. Geological Survey No. 92, p. 19.

The largest spring flood during this period occurred from February 27 to March 6, 1902.[a] The maximum rate of flow was 30.2 second-feet per square mile. This flood was due to melting snow, accompanied by rain on frozen ground.

The largest flood due to rain alone occurred October 7-10, 1903,[b] when the miximum rate of flow was 43.4 second-feet per square mile—that is, 44 per cent greater than that of March 2, 1902. The precipitation for the three days October 8-11 over this watershed was 11.74 inches. The precipitation during the preceding months was above the normal, so that the ground and surface reservoirs could absorb only a small part of the water that fell during the storm.

[a] This flood and the damage wrought by it is treated in Water-Supply and Irrigation Paper No. 88.
[b] This flood and the damage wrought by it is treated in Water-Supply and Irrigation Paper No. 92.

RARITAN RIVER.

The Raritan is the largest river of New Jersey. Its basin is long and narrow and comprises an area of 1,105 square miles. The upper part is mountainous and has a rapid run-off. The lower part is hilly or rolling with grass-covered or cultivated slopes. Less than 13 per cent of the whole area is forested. The topography of this basin is very different from that of the Passaic, which lies just north of it. The rain falling on all parts of the basin runs off quickly, so that the floods are shorter than in the Passaic and inflict less damage.

The following table gives the daily rate of flow of this stream during the large floods from 1810 to 1905, and the date of occurrence of each:

Flood flow of Raritan River at New Brunswick and Boundbrook, N. J.[a]

[Drainage area above Boundbrook, 806 square miles.]

Year.	Date.	Gage height.	Discharge.	Year.	Date.	Gage height.	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1810	November 24	([b])			October 10	[e] 12.0	28,500
1865	July 17	([b])			October 11	[e] 6.5	10,840
1874	September 18	9.0			October 12	[e] 5.2	7,500
1882	September 22		[d] 7,000		October 13	[e] 3.5	3,800
	September 23	[c] 11.5	[d] 35,500	1904	February 22	9.5	19,950
	September 24	[c] 14.2	[d] 52,000		September 15	10.1	21,940
	September 25		[d] 7,000		September 16	5.5	8,230
1886	February 12	[c] 9.0		1905	January 7	10.4	22,960
1887	February 23	[c] 8.0			January 8	5.7	8,730
1889	November 28	[c] 8.0			March 9	6.0	9,500
1903	October 8	[e] 1.6	820		March 10	7.4	13,410
	October 9	[e] 7.9	14,900		March 11	5.7	8,730

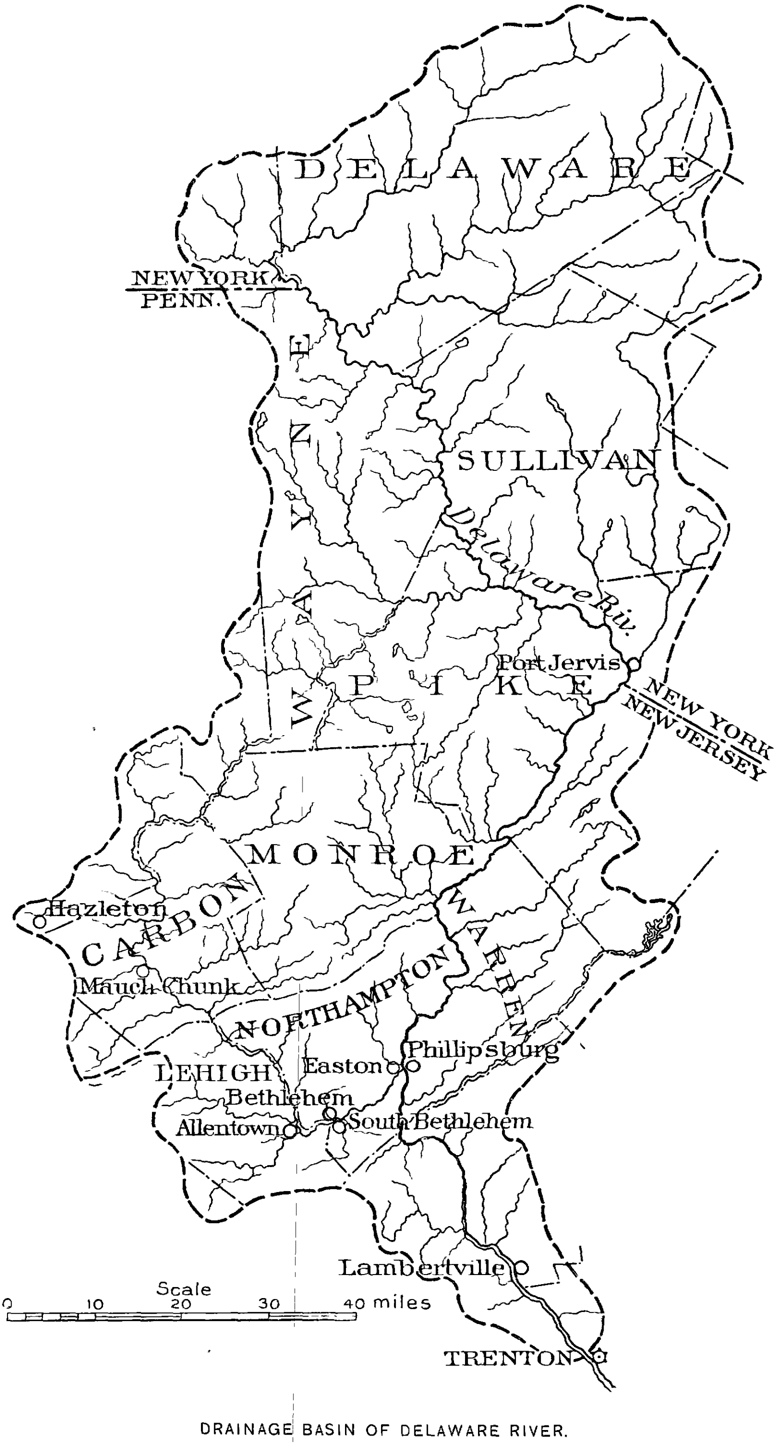
[a] A description of this station is given in Water-Supply and Irrigation Paper No. 97, p. 238.
[b] Not as great as in September, 1882.
[c] At Boundbrook dam.
[d] Geological Survey, New Jersey, 1894, vol. 3, p. 213.
[e] U. S. Geological Survey gaging station, Boundbrook, N. J.

There were four great floods in these ninety-five years. That of September 24, 1882, which had a maximum discharge at Boundbrook of 52,000 second-feet, or 64.5 second-feet per square mile, was probably the largest during this period. It was due to a long, heavy rain. During four days 12 inches of rain fell over this basin.

During the great flood in the Passaic River basin in October, 1903, the maximum rate of flow of the Raritan at Boundbrook was only 28,500 second-feet, or 35.3 second-feet per square mile.

DELAWARE RIVER.

The Delaware rises in the southeastern part of New York State, on a plateau that stands 1,800 to 1,900 feet above sea level, flows in a general southerly direction a distance of 410 miles, and empties into Delaware Bay (see Pl. III). From its source to Trenton, N. J., a distance of 280 miles, its average fall is 6.7 feet per mile. The basin is long and narrow, with steep slopes and little surface storage above Lambertville, N. J. The topographic features all favor a rapid run-off, hence the stream is subject to great and sudden fluctuations of flow.



DRAINAGE BASIN OF DELAWARE RIVER.

The following table gives the daily rate of flow of this stream at or near Lambertville, N. J., of the large floods from 1786 to 1905.

Flood flow of Delaware River at Lambertville, N. J.[a]

[Drainage area, 6,855 square miles.]

Year.	Date.	Gage height.[b]	Discharge.	Year.	Date.	Gage height.[b]	Discharge.
		Feet.	*Second-feet.*			*Feet.*	*Second-feet.*
1786	October 6	16.0	175,000	1902	March 3	16.4	132,600
1801		14.0	140,000-160,000		March 4	12.5	92,450
1814		14.0	115,000		March 5	9.4	60,470
1832	March	12.0	115,000		March 14	11.1	77,980
1836	April	14.5	140,000-150,000		March 15	10.2	68,710
1839	April	14.6	140,000-150,000		March 18	11.8	85,190
1841	January 8	20.0	254,600	1903	March 1	13.6	103,700
1843	October 13	14.0	140,000-150,000		March 2	12.9	96,520
1846	March 15	17.6	207,000		March 24	12.7	94,460
1862	June 8		223,600		March 25	12.4	91,370
1890	November 5		50,200		October 9	9.4	60,470
1891	January		109,100		October 10	20.2	171,700
1899	March 7	9.7	63,560		October 11	20.7	176,900
1900	February 14	11.4	81,070		October 12	12.7	94,460
	March 2	12.0	87,250		October 13	9.9	65,620
1901	March 22	10.5	71,800	1904	February 21	[c] 10.0	
	December 16	18.9	158,300		February 22	[c] 15.1	
1902	March 1	18.2	151,100		February 23	[c] 13.5	
	March 2	20.2	171,700	1905	March 28	11.9	86,220

[a] This station is described in Water-Supply and Irrigation Paper U. S. Geological Survey, No. 97 p. 249.
[b] Heights given for 1786 to 1846 are heights above low water. See Rept. New Jersey Geol. Survey for 1894, vol. 3, p. 235; and Rept. of Chief Engineer U. S. Army, for 1873, App. U, p. 19. Discharges have been computed from the gage heights given.
[c] Due to ice gorge.

According to these records the largest flood on this stream since 1786 occurred January 8, 1841, during which the rate of flow was 254,600 second-feet, or 37.1 second-feet per square mile. The largest in recent years was the great flood of October, 1903, the rate on the 11th being 176,900 second-feet, or 25.8 second-feet per square mile. The storm that produced the flood on this stream caused an unprecedented flood on the Passaic River.[a]

[a] Water-Sup. and Irr. Paper No. 92, U. S. Geological Survey, 1904.

SUSQUEHANNA RIVER.

The Susquehanna, the largest river on the Atlantic slope, rises in Otsego Lake, New York, at an elevation of about 1,193 feet above sea level. It falls this height in 422 miles, but its fall per mile, unlike that of most streams, is greater in the 43 miles just above its mouth than in any other part of its course. In these 43 miles it falls 231 feet.

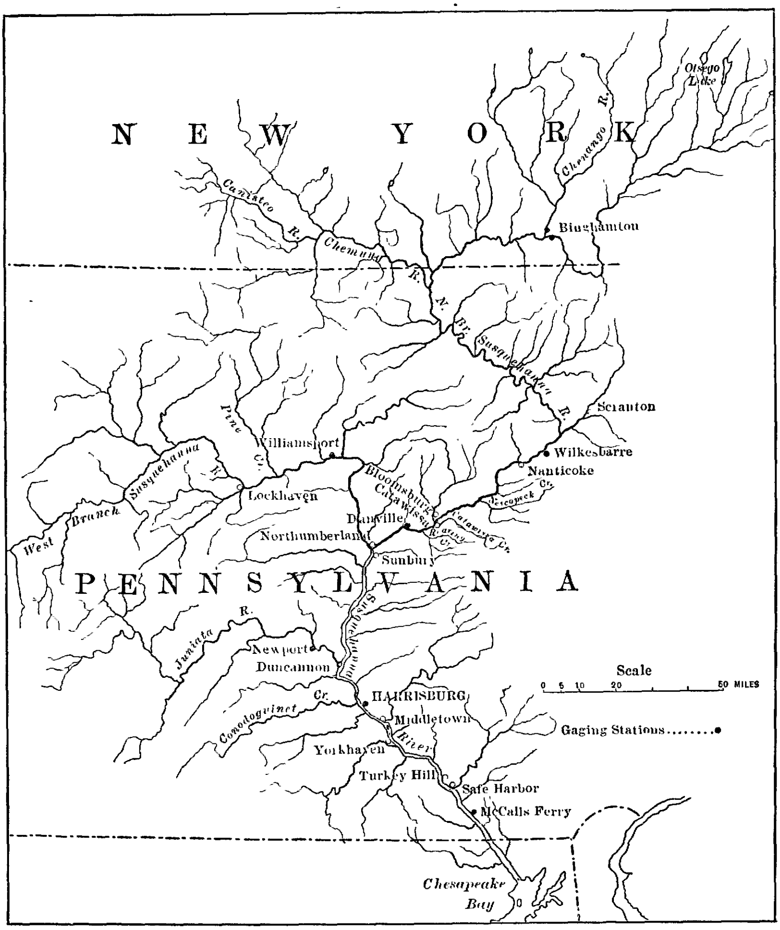


FIG. 11.—Map of drainage basin of Susquehanna River.

The basin is fan shaped, being nearly as broad as it is long, and has an area of 27,400 square miles. Its topography is extremely varied in character. The upper part is a plateau—a rolling country with moderately rapid run-off. Nearly all the remainder is mountainous, with steep slopes, little forest area, little surface storage, and comparatively little ground storage. Spring freshets, due to the rapid melting of the winter's snow and to ice gorges in the streams, are of frequent occurrence.

The following table gives the daily rate of flow at Harrisburg during the large floods that have occurred from 1865 to 1905, and the date of each:

Flood flow of Susquehanna River at Harrisburg, Pa., 1865–1905.[a]

[Drainage area, 24,030 square miles. Danger line, 17 feet gage height.]

Year.	Date.	Gage height.	Discharge.	Year.	Date.	Gage height.	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1865	March		([b])	1901	December 17	18.6	323,380
			670,000		December 18	14.2	215,720
1889	June		to		December 19	9.8	134,900
			735,000	1902	February 28	9.7	133,150
1891	February 18	14.3	217,580		March 1	20.3	371,950
	February 19	19.0	234,500		March 2	23.9	483,760
	February 20	17.8	301,460		March 3	23.3	464,320
	February 21	13.3	198,700		March 4	21.4	404,800
1893	May 4	6.8	82,900		March 5	16.3	262,240
	May 5	16.2	259,660		March 6	12.3	179,960
	May 6	16.5	267,400	1903	March 1	13.4	200,600
	May 7	14.6	223,240		March 2	16.8	275,200
1894	May 21	16.3	262,240		March 3	14.5	221,300
	May 22	25.6	540,720	1904	March 5	[c]128.0	141,100
	May 23	21.4	404,800		March 6	[c]128.0	141,100
	May 24	15.3	237,780		March 7	[c]126.4	118,500
1898	March 23	10.9	154,480		March 8	[c]146.6	[d]300,000
	March 24	15.6	244,740		March 9	[c]130.2	176,500
	March 25	15.3	237,780		March 10	[c]130.4	180,700
	March 26	11.7	168.980		March 11	[c]130.9	192,000
1901	December 15	9.3	126,050	1905	March 21	15.7	283,700
	December 16	21.4	404,800				

[a] For description of gaging station and station rating table see Water-Sup. and Irr. Paper No 109, pp. 104 and 115.
[b] Approximately the same as during flood of June, 1889.
[c] At McCall Ferry. Above sea level.
[d] Approximate maximum discharge, 631,000 second-feet.

Four very large floods have occurred during this period. Two of these occurred in March and were due to rapid melting of snow and to ice gorges, and two occurred later in the year and were due to rainfall alone. The flood of June, 1889, was the largest and had a maximum rate of from 28 to 30.6 second-feet per square mile at Harrisburg. The storm causing this flood lasted about thirty-four hours. During this time from 4 inches to 9 inches of rain fell.[a]

This flood reached a stage of 33.5 feet above low water at Williamsport, on the West Branch. The highest stage at this place during the flood of 1865 was 27 feet.

This flood was very large on Chemung River, a northern tributary of the Susquehanna. The maximum rate of flow at Elmira on June 1 from 2,055 square miles was 67 second-feet per square mile.[b]

The flood of March, 1904, is described in Water-Supply Paper No. 147, pages 22 to 32.

POTOMAC RIVER.

The Potomac is formed by the union of its north and south branches 15 miles below Cumberland, Md. From Cumberland to Georgetown the river falls 610 feet in 185 miles. The basin is long and comparatively narrow and has an area of 14,500 square miles. The basins of both branches of the Shenandoah, its principal tributary, are also long and narrow. The greater part of the Potomac basin is mountainous, with steep, nearly impervious slopes, little forest area, and no surface storage. All the topographic features favor rapid run-off; hence floods are frequent, sudden, and large. The valley of the Shenandoah is somewhat broader than that of the Potomac, and the range of surface fluctuation of the stream is not so great.

[a] Rept. Chief Engr. U. S. Army, 1891, p 1105. Also Eng. News, vol. 21, p. 528.
[b] Report of Francis Collingwood on "Protection of Elmira, N. Y against floods"

The following table gives the daily rate of flow of this stream during the large floods from 1889 to 1905 and the date of occurrence of each:

Flood flow of Potomac River at Point of Rocks, Md., 1889–1905.[a]

[Drainage area, 9,650 square miles.]

Year.	Date.	Gage height.	Discharge.	Year.	Date.	Gage height.	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1877	....	[b]	....	1901	May 23	12.6	82,580
1889	June 2	....	[c] 470,000		May 24	14.2	95,860
1895	March 3	10.6	65,980		May 25	9.3	55,190
1896	September 30	5.3	25,380		December 15	8.1	45,500
	October 1	21.9	159,800		December 16	17.2	120,800
	October 2	12.1	78,430		December 17	13.3	88,390
1897	February 22	6.7	34,900		December 18	6.9	36,340
	February 23	21.2	154,000		December 29	4.4	19,840
	February 24	24.6	182,200		December 30	13.8	92,540
	February 25	16.8	117,400		December 31	18.4	130,700
	May 3	6.5	33,480	1902	January 1	11.7	75,110
	May 4	14.0	94,200		February 25	4.4	19,840
	May 5	8.5	48,700		February 26	17.8	125,700
	May 14	8.9	51,900		February 27	27.2	203,800
	May 15	12.6	82,580		February 28	18.0	127,400
	May 16	8.0	44,720		March 1	22.5	164,800
1898	August 10	5.6	27,340		March 2	29.0	218,700
	August 11	14.0	94,200		March 3	16.1	111,600
	August 12	16.1	111,600		March 4	10.2	62,660
	August 13	9.5	56,850		March 11	12.0	77,600
	October 22	5.4	26,020		March 12	12.4	80,920
	October 23	13.1	86,730		March 13	14.0	94,200
	October 24	10.1	61,830		March 14	13.8	92,540
1899	February 22	8.5	48,700		March 15	12.0	77,600
	February 23	14.8	100,800		March 16	10.2	62,660
	February 24	13.7	91,710		April 8	6.4	28,780
	February 25	9.0	52,700		April 9	16.4	108,700
	February 27	9.3	55,190		April 10	14.3	91,290
	February 28	13.9	93,370		April 11	12.9	79,670
	March 1	11.9	76,770		April 12	12.2	73,860
	March 2	9.2	54,360		April 13	11.5	68,050
	March 5	8.5	48,700	1903	February 28	5.4	22,300
	March 6	16.6	115,800		March 1	14.2	90,460
	March 7	12.9	85,070		March 2	15.3	99,590
	March 8	10.0	61,000		March 3	8.9	46,820
1901	March 11	4.2	18,680		March 24	7.0	32,820
	March 12	12.4	80,920		March 25	12.1	73,030
	March 13	9.9	60,170		March 26	8.6	44,500
	April 15	9.0	52,700		April 14	5.6	23,560
	April 16	15.0	102,500		April 15	14.4	92,120
	April 17	8.3	47,100		April 16	15.1	97,930
	April 20	5.4	26,020		April 17	14.0	88,800
	April 21	11.4	72,620		April 18	10.4	58,920
	April 22	20.8	150,600	1905	March 10	6.4	28,780
	April 23	15.8	109,100		March 11	11.0	63,900
	April 24	11.2	70,960		March 12	10.1	56,430
	April 25	7.9	43,940		March 13	6.9	32,140
	May 22	1.9	....				

[a] Description of this station is given in Water-Sup. and Irr. Paper U. S. Geol. Survey No. 167, p. 55.
[b] See Rept. Chief of Engrs. U. S. Army, 1881, p. 940, for comparisons of floods of 1877 and 1881.
[c] Discharge at Chain Bridge.

The largest flood, except for that of 1889, in the lower part of this basin occurred in February, 1881, and was due to an ice gorge.[a] The stage at Long Bridge, Washington, D. C., was 2.5 feet greater than during the flood of 1877. About 254 acres of the city of Washington was submerged during this flood.

On June 2, 1889, occurred the largest flood on this stream. Above Harpers Ferry [b] it reached a stage of 34 feet above low water and 6.8 feet above that attained during the flood of 1877. The mean rate of flow June 2 at Chain Bridge, Washington, was 40.9 second-feet per square mile from 11,500 square miles of area.

The storm [c] causing this flood extended from Kansas to the Atlantic and from the Great Lakes to the Carolinas. It caused unprecedented floods in the Susquehanna River basin, and to it was due the great disaster at Johnstown, Pa.

The largest flood since 1889 was on March 2, 1902, when the discharge was 218,700 second-feet at Point of Rocks.

CAPE FEAR RIVER.

Cape Fear River is formed by the junction of New and Deep rivers in Chatham County, N. C., flows 192 miles in a general southeasterly direction, and empties into the Atlantic Ocean. Steamers of light draft ascend the river to Fayetteville, a distance by river of 160 miles. From Fayetteville up to Smileys Falls, a distance of 25 miles, the fall is only 1.25 feet per mile.

The basin above Fayetteville is long and narrow and has an area of 3,860 square miles. It is gently rolling or hilly, with thin soil that absorbs moisture slowly. The run-off into the main channel is therefore large and rapid and the floods on this stream are more violent than those on any other stream in North Carolina.

The following table gives the stages of this stream at Fayetteville during all the large floods from 1889 to 1902 and the approximate daily discharge during some of them:

[a] Rept. Chief of Engrs. U. S. Army, 1881, p. 940.
[b] Rept. Chief of Engrs. U. S. Army, 1889, p. 985.
[c] Eng. News, vol. 21, p. 528.

Flood flow of Cape Fear River at Fayetteville, N. C., 1889-1904.[a]

[Drainage area, 3,860 square miles. Danger line, 38 feet gage height.]

Year.	Date.	Gage height.[b]	Discharge.
		Feet.	*Sec.-feet.*
1889	February 20	43.0	
	June 1	10.0	
	June 2	40.0	
	June 3	30.0	
	July 3	43.9	
	July 29	45.0	53,000 to 58,000
	August 1	44.2	
1891	March 14	41.0	
	May 30	45.1	
	August 24	43.1	
1892	January 21	49.5	55,000 to 65,000
1893	February 15	42.3	
	October 24	42.0	
1894	October 12	47.9	
1895	January 10	37.0	
	January 11	52.0	
	January 12	58.0	70,000 to 90,000
	January 13	56.0	
	January 14	47.4	
	January 15	38.0	
	March 22	41.0	
1895	April 10	47.7	
	May 1	44.6	
1896	February 8	48.0	
	July 11	49.5	
1899	February 9	52.0	
	February 20	43.0	
	March 17	42.0	
1900	April 21	44.0	
	April 22	44.0	
1901	April 5	47.7	
	May 22	14.0	
	May 23	48.0	
	May 24	58.5	70,000 to 90,000
	May 25	54.7	
	May 26	42.0	
	May 27	33.9	
	July 15	41.5	
	August 15	42.0	
	September 20	43.6	
1902	February 4	40.3	
	March 2	41.7	
1903	March 25	50.5	55,000 to 65,000

[a] A description of this gaging station is given in Water-Sup. and Irr. Paper U. S. Geol. Survey No. 83, p. 31.
[b] U. S. Weather Bureau gage records.

NOTE.—The lowest stage was 0.7 foot on the gage October 5, 1895, and the flow was 0.069 second-foot per square mile.

The largest flood during this period occurred in May, 1901, and reached a stage of 58.5 feet, or about 58 feet above low water. The discharge is estimated to have been from 70,000 to 90,000 second-feet, or from 18 to 23 second-feet per square mile. High stages occur often in this stream, and in nearly all months of the year. The rise and fall are very rapid. The very great range of stage at this place is due to the small slope of the stream bed and the small channel, which is U-shaped, with high banks and small bottom width. At the junction of New and Deep rivers, where the slope and width are greater than at Fayetteville, the range of stage is about 25 feet. It is reported that the stage at Fayetteville has been 75 feet.

SAVANNAH RIVER.

Savannah River is formed by the junction of Tugaloo and Seneca rivers in the northern part of North Carolina, about 100 miles north of Augusta, flows in a southerly direction a distance of 355 miles by river, and empties into the Atlantic Ocean at Savannah The stream is navigable to Augusta, a distance by river of 248 miles. The fall in this distanee is above 130 feet. From Augusta to Andersonville, a distance of 107 miles, the fall is 270 feet. The basin is long and narrow and comprises a drainage area above Augusta of 7,500 square miles. The upper part extends well up into the Blue Ridge Mountains and has a rapid run-off. Numerous comparatively small streams enter the main stream at considerable distances apart. This stream is subject to large freshets, due to rain and the rapid melting of snow in the mountains in the spring. The greatest flood, however, occurred in September, and was due to rain alone.

The following table gives the daily rate of flow of this stream at Augusta, Ga., during all the large floods from 1840 to 1905:

Flood discharge of Savannah River at Augusta, Ga., 1840–1905.[a]

[Drainage area, 7,500 square miles. Danger line, 32 feet. Lowest stage, 2.5 feet.]

Year.	Date.	Gage height.[b]	Discharge.	Year.	Date.	Gage height.[b]	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1840	May 28	37.8	[c] 253,000	1888	September 12	33.9	138,300
1852	August 29	36.8	[c] 220,000		September 13	23.2	47,560
1865	January 11	36.4	[c] 202,000	1889	February 18	30.6	109,300
1878	July 31	34.5	[c] 143,000		February 19	32.9	129,500
1888	September 11	38.7	[c] 300,000		February 20	29.3	97,840
1881	March 17	28.5	90,800	1891	March 9	31.2	114,600
	March 18	32.2	123,360		March 10	35.3	165,400
	March 19	23.3	47,660		March 11	32.6	126,900
1886	March 31	30.8	111,040		March 12	27.7	83,760
	April 1	32.2	123,360		March 13	31.2	114,600
	April 2	29.0	95,200		March 14	29.5	99,600
	May 20	28.7	92,560	1892	January 20	31.0	112,800
	May 21	32.5	126,000		January 21	32.5	126,000
	May 22	26.8	75,840		January 22	26.8	75,840
1887	July 29	14.0	17,900	1896	July 9	29.2	96,960
	July 30	32.3	124,200			30.2	105,800
	July 31	34.5	143,600			25.8	67,040
	August 1	32.0	121,600	1899	February 7	28.0	86,400
	August 2	28.1	87,280		February 8	31.0	112,800
	August 3	31.7	119,000		February 9	29.9	103,100
	August 4	32.1	122,500	1900	February 13	29.6	100,500
	August 5	23.9	51,380		February 14	32.3	124,200
	August 9	30.8	111,000		February 15	22.1	41,480
	August 10	33.0	130,400	1902	February 28	25.5	64,400
	August 11	24.0	52,000		March 1	33.8	137,400
1888	March 29	30.6	109,300		March 2	33.3	133,000
	March 30	32.7	127,800		March 3	28.6	91,680
	March 31	29.8	102,200	1903	February 8	30.7	110,200
	September 9	23.5	48,900		February 9	33.0	130,400
	September 10	34.7	148,600		February 10	28.7	92,560
	September 11	38.1	276,500	1905	February 14	25.3	62,700

[a] Description of station in Water-Sup and Irr Paper U S Geol Survey No 98 p. 57

[b] Property of city of Augusta, Ga

[c] House Document No 213 51st Cong 1st sess

The largest flood at this place during the period covered by the table occurred September 11, 1888.[a] The maximum stage was 38 7 feet and the maximum rate of flow was 40 second-feet per square mile The normal rainfall for September at Augusta is 2 to 4 inches. The rainfall for September, 1888, was 12 inches. The water was from 1 foot to 12 feet deep over a part of the city of Augusta, and the flood did a large amount of damage.

Second in size was the flood of 1840, during which the maximum rate of flow was 33.7 second-feet per square mile.

[a] Report on survey of the Savannah River above Augusta, Ga., House Doc 213, 51st Cong , 1st sess.

ALABAMA RIVER.

Alabama River is formed by the junction of the Coosa and Tallapoosa rivers 6 miles above Montgomery, Ala. The drainage basin of these streams is hilly country, well wooded, and about one-fourth of the land is under cultivation. The streams have comparatively little fall, a sluggish flow, and are subject to great fluctuations of stage. The channel is deep and the area flooded comparatively small for such extreme fluctuations of stage.

The following table gives the daily rate of flow of the Alabama at Selma, Ala., of the large floods from 1891 to 1904:

Flood flow of Alabama River at Selma, Ala., 1891 to 1904. [a]

[Drainage area, 15,400 square miles. Lowest water, −1.9 feet, November 9, 1894. Danger line, 35 feet.]

Year.	Date.	Gage height.[b]	Discharge.	Year.	Date.	Gage height.[b]	Discharge.
		Feet.	*Sec. feet.*			*Feet.*	*Sec. feet.*
1891	March 13	47.3	127,260	1900	February 17	48.0	129,200
	March 14	48.0	129,200		February 18	47.9	128,900
	March 15	47.6	128,100		April 23	41.0	110,000
1892	January 16	50.3	135,500		April 24	40.0	107,200
	January 17	52.2	140,800	1901	January 17	40.0	107,200
	January 18	53.8	145,200		April 23	39.0	104,400
	January 19	54.0	145,700	1902	January 2	45.0	121,000
	January 20	53.7	144,900		January 3	46.6	125,400
	January 21	52.8	142,400		January 4	46.3	124,500
	January 22	52.4	141,300		March 4	47.1	126,700
	January 23	52.1	140,500		March 5	47.1	126,700
	January 24	52.1	140,500		March 6	46.2	124,200
	January 25	51.3	138,300		March 7	44.4	119,300
	March 29	48.3	130,000		March 31	48.9	131,700
	March 30	48.5	130,600		April 1	50.1	135,000
	April 14	46.0	123,700		April 2	50.7	136,600
1893	February 20	44.0	118,200		April 3	50.0	134,700
	February 21	44.6	119,800		April 4	48.6	130,800
	February 22	43.9	117,900	1903	February 12	48.0	129,200
1895	March 19	41.8	112,200		February 13	49.5	133,300
	March 20	42.6	114,400		February 14	50.2	135,200
	March 22	41.8	112,200		February 15	50.6	136,400
1897	March 17	40.7	109,200		February 16	49.9	134,400
1899	March 3	38.8	103,900		February 17	49.0	132,000

[a] For description of station, see Water-Sup. and Irr. Paper No. 83, p. 131.
[b] U. S. Weather Bureau records.

The largest flood during this period occurred in January, 1892. The stream was nearly 56 feet above low water and the maximum rate of flow was 145,700 second-feet, or 9.5 second-feet per square mile. High stages occur nearly every year and last from one or two weeks to a month. The flood flow is comparatively small and these high stages are due to narrow channel and small slope of stream bed.

BLACK WARRIOR RIVER.

Black Warrior River is formed by the junction of the Mulberry and Sipsey forks at Warriortown, Ga., flows in a southerly direction and empties into the Tombigbee. The basin is rolling or flat open country, much of which is under cultivation. The stream has little fall and its flow is sluggish. The area above the gaging station at Tuscaloosa, Ala., is 4,900 square miles.

The following table gives the daily flow at this station during the large floods from 1889 to 1905:

Flood flow of Black Warrior River at Tuscaloosa, Ala., 1889–1905. [a]

[Drainage area, 4,900 square miles. Danger line, 43.0 feet gage height. Lowest stage, — 0.8 foot.]

Year.	Date.	Gage height.[b]	Discharge.	Year.	Date.	Gage height.[b]	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1889	January 18	40.5	63,000	1895	March 17	52.0	109,000
	February 18	56.4	126,600		March 18	47.3	90,200
	February 19	56.6	127,400		March 22	51.3	106,200
	February 20	53.0	113,000	1897	March 7	51.4	106,600
1890	February 9	54.0	117,000		March 8	54.8	120,200
	February 10	52.9	112,600		March 9	51.6	107,400
	March 1	58.9	136,600		March 14	51.0	105,000
	March 2	57.4	130,400	1898	January 27	43.5	75,000
	March 3	52.4	110,600		April 6	38.7	55,800
	April 5	45.9	....	1899	January 8	49.3	98,200
1891	February 8	51.5	107,000		February 6	50.6	103,400
	February 9	51.5	107,000		February 7	51.4	106,400
	February 10	52.2	109,800		February 8	51.7	107,800
	February 11	53.5	115,000		February 9	48.6	95,400
	February 12	50.5	103,000		March 16	59.3	138,200
	February 13	47.6	91,400		March 17	60.3	142,200
	February 14	51.4	106,600		March 18	57.7	131,800
	February 15	49.5	99,000		March 19	52.4	110,600
	March 7	53.0	113,000		March 20	49.3	98,200
	March 8	58.0	133,000		December 13	39.5	59,000
	March 9	60.4	142,600	1900	February 14	48.0	93,000
	March 10	58.0	133,000		March 21	51.0	105,000
	March 11	54.0	117,000		April 12	52.8	112,200
1892	January 13	53.0	113,000		April 13	53.4	114,600
	January 14	57.4	130,600		April 14	48.7	95,800
	January 15	55.9	124,600		April 17	63.0	153,000
	January 16	51.7	107,800		April 18	64.0	157,000
	April 6	11.6	....		April 19	62.2	149,800
	April 7	56.3	126,200		April 20	59.4	138,600
	April 8	63.2	153,800		April 21	56.1	125,400
	April 9	62.2	149,800		April 22	51.7	107,800
	April 10	58.0	133,000		April 23	46.2	85,800
	April 11	52.3	110,200		June 24	50.0	101,000
	April 12	45.4	....		June 25	58.4	134,600
	April 13	40.7	....		June 26	56.4	126,600
	April 14	36.5	....		June 27	52.9	112,600
	July 11	46.2	85,800		June 28	49.1	97,400
1893	February 16	52.2	109,800	1901	January 12	52.7	111,800
	February 17	55.6	123,400		January 13	56.5	127,000
	February 18	54.7	119,800		January 14	53.3	114,200
	February 19	51.4	106,600		January 15	47.3	90,200
	May 4	51.2	105,800		February 5	42.0	69,000
	May 5	52.2	109,800		April 21	42.6	71,400
	May 6	48.0	93,000		December 30	49.0	97,000
	June 3	49.6	99,400		December 31	49.0	97,000
	June 4	46.0	85,000	1902	January 1	44.0	77,000
1895	January 9	50.6	103,400		February 3	48.4	94,600
	January 10	49.3	98,200		March 1	49.9	100,600

[a] Description of station in Water-Sup. and Irr. Paper No. 98, p. 159.
[b] U. S. Army Engineers records.

Flood flow of Black Warrior River at Tuscaloosa, Ala., 1889–1905—Continued.

Year.	Date.	Gage height.	Discharge.	Year.	Date.	Gage height.	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1902	March 28	60.4	142,600	1903	February 17	56.7	127,800
	March 29	60.6	143,400		February 18	56.8	128,200
	March 30	58.3	134,200		February 19	53.0	113,000
	March 31	57.4	130,600		March 1	54.3	118,200
	April 1	52.9	112,600		May 16	43.4	74,600
1903	February 8	56.4	126,600	1905	January 14	46.1	85,400
	February 9	55.9	124,600		February 9	55.5	123,000
	February 10	51.5	107,000		February 10	56.9	128,000
	February 11	52.0	109,000		February 11	54.5	119,000
	February 12	53.8	116,200		February 22	47.7	91,800
	February 13	51.1	105,400				

The largest flood during this period was in April, 1900. The stage on the 18th was 64 feet, or about 64.8 feet above low water. The maximum daily rate was 157,000 second-feet, or 32 second-feet per square mile. This great range of stage is due to sluggish flow and narrow, deep channel. They last from one to three or four weeks.

It is reported that the stage at this place has been 87.6 feet.

MONONGAHELA RIVER.

The Monongahela rises in the north-central part of West Virginia, flows in a general northerly direction, and joins the Allegheny at Pittsburg to form the Ohio (see Pl. IV). Its principal tributaries are the Cheat, which enters from the east a few miles north of the southern boundary of Pennsylvania, and the Youghiogheny, which enters from the east at McKeesport. The basin of the Monongahela has an area of 7,625 square miles, embracing the west slope of the Allegheny Mountains. It is mainly mountainous or hilly, with no surface storage and little forest area, and stands at a higher elevation than the Ohio basin, immediately west of it. From Fairmount to the mouth of the stream, a distance of 123 miles, the fall of the river is about 1.1 feet per mile. This part of the stream consists of a series of slack-water basins formed by dams.

The following table gives the daily rate of flow of the Monongahela at Lock No. 4 during all the large floods from 1886 to 1905:

Flood flow of the Monongahela River at Lock No. 4, Pennsylvania, 1886–1905.

[Drainage area, 5,430 square miles. Lowest stage, 3.2 feet. Danger line, 28 feet.]

Year.	Date.	Gage height.[a]	Discharge.	Year.	Date.	Gage height.[a]	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1886	March 31	16.5	33,600	1886	May 12	10.2	....
	April 1	27.0	92,600		May 13	15.3	28,150
	April 2	23.5	70,800		May 14	21.2	57,900
	April 3	16.0	31,300		May 15	24.3	75,600
	April 5	18.5	43,600		May 16	16.5	33,600
	April 6	25.0	79,800	1887	February 3	14.0	22,500
	April 7	26.0	85,800		February 4	31.0	120,600
	April 8	19.5	48,600		February 5	24.5	76,800
	May 8	6.5	....		February 6	16.3	32,650
	May 9	22.0	62,300		February 26	11.7	14,500
	May 10	16.5	33,600		February 27	28.0	99.600
	May 11	11.5	....		February 28	24.0	73,800

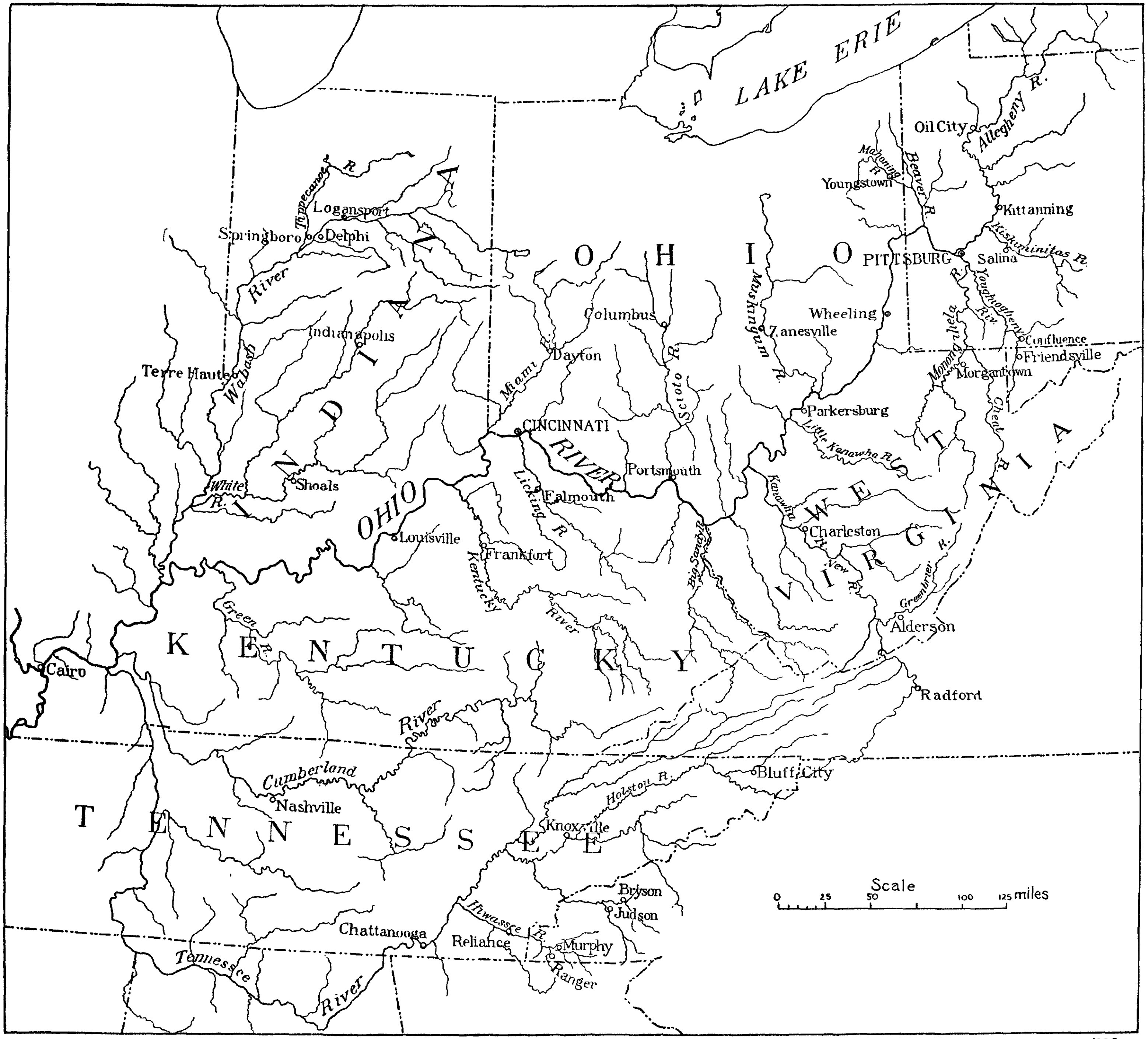
[a] U. S. Weather Bureau records.

Flood flow of the Monongahela River at Lock No. 4, Pennsylvania, 1886–1905—Continued.

Year.	Date.	Gage height.	Discharge.
		Feet.	*Sec.-feet.*
1887	March 1	16.3	32,650
1888	January 8	19.5	48,600
	January 9	20.7	55,150
	January 10	16.5	33,600
	July 9	6.9	....
	July 10	26.0	85,800
	July 11	42.0	207,000
	July 12	27.0	92,600
	July 13	14.5	....
1889	February 17	12.7	17,490
	February 18	27.0	92,600
	February 19	25.5	82,800
	February 20	19.5	48,600
	April 13	13.0	18,540
	April 14	21.0	56,800
	April 15	17.7	39,600
	May 31	8.7	....
	June 1	25.0	79,800
	June 2	19.4	48,100
	November 9	11.9	15,000
	November 10	21.4	59,000
	November 11	18.0	41,100
1890	January 7	10.0	....
	January 8	20.5	54,050
	January 9	20.0	51,300
	January 10	16.4	33,100
	February 3	10.8	....
	February 4	21.1	57,350
	February 5	21.1	57,350
	February 6	16.2	32,200
	February 20	11.0	....
	February 21	23.5	70,800
	February 22	19.5	48,600
	March 22	19.5	48,600
	March 23	31.8	126,200
	March 24	28.5	103,100
	March 25	18.8	45,100
	October 12	11.8	14,800
	October 13	20.1	51,850
	October 14	24.3	75,600
	October 15	21.5	59,550
	October 16	15.0	26,800
1891	January 1	9.0	....
	January 2	27.0	92,600
	January 3	31.3	122,700
	January 4	20 8	55,700
	January 5	14.1	22,920
	February 10	17.0	36,100
	February 11	24.0	73,800
	February 12	18.8	45,100
	February 16	12.3	16,210
	February 17	21.8	61,200
	February 18	20.5	54,050
	February 19	16.3	32,650
1891	February 22	19.0	46,100
	February 23	20.4	53,500
	February 24	15.3	28,150
1892	January 13	11.0	....
	January 14	25.7	84,000
	January 15	28.5	103,100
	January 16	19.3	47,600
	April 23	18.0	41,100
	April 24	21.6	60,100
	April 25	15.5	29,050
1893	January 29	16.5	33,600
	January 30	23.5	70,800
	January 31	18.2	42,100
1895	January 6	7.3	....
	January 7	24.5	76,800
	January 8	30.0	113,600
	January 9	22.0	62,300
	January 10	15.8	30,400
	January 11	21.9	61,750
	January 12	19.0	46,100
	March 15	14.5	24,600
	March 16	21.0	56,800
	March 17	21.7	60,650
	March 18	16.4	33,100
1896	March 19	11.2	....
	March 20	20.5	54,050
	March 21	18.6	44,100
	July 30	14.2	23,340
	July 31	25.3	81,600
	August 1	24.0	73,800
	August 2	15.6	29,500
1897	February 22	16.0	31,300
	February 23	36.0	159,000
	February 24	36.0	159,000
	February 25	23.0	67,800
	February 26	14.0	22,500
	May 14	19.7	49,650
	May 15	20.6	54,600
	May 16	14.6	25,040
	December 5	8.0	....
	December 6	20.6	54,600
	December 7	15.6	29,500
1898	January 10	14.0	22,500
	January 11	23.9	73,200
	January 12	20.0	51,300
	January 13	15.8	30,400
	January 16	19.5	48,600
	January 17	21.0	56,800
	January 18	16 0	31,300
	January 23	13.5	20,480
	January 24	21.9	61,750
	January 25	16.7	34,600
	March 17	8.5	....
	March 18	20.0	51,300

Flood flow of the Monongahela River at Lock No. 4, Pennsylvania, 1886–1905—Continued.

Year.	Date.	Gage height.	Discharge.	Year.	Date.	Gage height.	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1898	March 19	16.7	34,600	1901	May 28	21.3	58,450
	March 20	12.7	....		May 29	20.0	51,300
	March 21	13.8	21,680		May 30	17.1	36,600
	March 22	22.5	65,050		December 15	18.5	43,600
	March 23	20.7	55,150		December 16	28.5	103,100
	March 24	20.2	52,400		December 17	18.5	43,600
	March 25	24.7	78,000		December 29	16.5	33,600
	March 26	23.8	72,600		December 30	25.0	79,800
	March 27	16.0	31,300		December 31	22.0	62,300
	March 28	12.5	....	1902	January 27	9.5	....
	March 29	12.0	15,300		January 28	25.9	85,200
	March 30	23.9	73,200		January 29	19.5	48,600
	March 31	20.7	55,150		February 26	16.4	33,100
	April 1	14.5	24,600		February 27	21.5	59,550
	August 10	17.3	37,600		February 28	18.8	45,100
	August 11	23.3	69,600		March 1	29.5	110,100
	August 12	21.0	56,800		March 2	25.1	80,400
	August 13	17.8	40,100		March 3	20.0	51,300
	October 22	14.0	22,500		March 4	15.6	29,500
	October 23	21.6	60,100		March 9	11.3	....
	October 24	15.8	30,400		March 10	21.6	60,100
1899	January 6	15.0	26,800		March 11	19.6	49,100
	January 7	23.5	70,800		April 9	17.2	37,100
	January 8	23.0	67,800		April 10	20.1	51,850
	January 9	15.6	29,500		April 11	22.0	62,300
	February 4	11.5	....		April 12	22.7	66,150
	February 5	22.0	62,300		April 13	21.5	59,550
	February 6	17.5	38,600		April 14	17.7	39,600
	March 5	14.0	22,500		December 12	20.0	51,300
	March 6	26.9	91,900		December 13	25.0	79,800
	March 7	20.0	51,300		December 14	26.2	87,000
	March 28	9.5	....		December 15	19.0	46,100
	March 29	23.0	67,800		December 16	17.0	36,100
	March 30	23.0	67,800		December 17	26.0	85,800
	March 31	16.5	33,600		December 18	20.5	54,050
1900	March 1	10.2	....		December 19	14.5	24,600
	March 2	21.0	56,800	1903	January 3	10.9	....
	March 3	19.0	46,100		January 4	22.1	62,850
	November 26	17.6	39,100		January 5	18.9	45,600
	November 27	33.8	141,400		February 4	16.0	31,300
	November 28	22.6	65,600		February 5	21.7	60,650
	November 29	14.8	25,920		February 6	17.8	40,100
1901	April 4	18.8	45,100		February 15	10.5	....
	April 5	21.6	60,100		February 16	22.6	65,600
	April 6	20.6	54,600		February 17	28.4	102,400
	April 7	23.1	68,400		February 18	19.2	47,100
	April 8	21.6	60,100		February 28	14.6	25,040
	April 9	17.0	36,100		March 1	32.5	131,100
	April 19	12.0	15,300		March 2	24.6	77,400
	April 20	23.3	69,600		March 3	15.7	29,950
	April 21	25.5	82,800		March 23	13.0	18,540
	April 22	21.5	59,550		March 24	23.2	69,000
	April 23	17.2	37,100		March 25	21.0	56,800
	May 27	19.4	48,100		March 26	14.6	25,040



DRAINAGE BASIN OF OHIO RIVER.

Flood flow of the Monongahela River at Lock No. 4, Pennsylvania, 1886–1905—Continued.

Year.	Date.	Gage height.	Discharge.	Year.	Date.	Gage height.	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1904	January 22	13.8	21,680	1905	March 8	12.0	15,300
	January 23	21.2	57,900		March 9	21.0	56,800
	January 24	20.0	51,300		March 10	28.3	101,700
	January 25	14.5	24,600		March 11	29.3	108,700
	March 23	14.2	23,340		March 12	18.5	43,600
	March 24	20.2	52,400		March 21	16.5	33,600
	March 25	16.8	35,100		March 22	27.2	94,000
1905	January 11	10.2	....		March 23	20.5	54,050
	January 12	24.3	75,600		March 24	13.4	20,080
	January 13	19.5	48,600				

The discharge is taken from a station rating table prepared from current-meter measurements of the flow at Belle Vernon, Pa., and surface slope data furnished by T. P. Roberts, Corps of Engineers, United States Army.

The gage is located at the lower end of the lock below the dam; its zero is 717.82 feet above sea level.

The greatest rate of discharge during this period was on July 11, 1888. The stream reached a stage of 42 feet, 38.8 feet above lowest stage, and a daily rate of flow of 207,000 second-feet, or 38.1 second-feet per square mile. Both the rise and fall during this flood were very rapid. It was due to a very heavy rain of comparatively short duration.

The flood second in size occurred February 23–24, 1897, when a stage of 36 feet was reached, and a rate of 159,000 second-feet, or 29.3 second-feet per square mile. It was a spring flood, due to rain and the rapid melting of snow.

YOUGHIOGHENY RIVER.

The Youghiogheny, the chief tributary of the Monongahela, drains an area of about 1,770 square miles. It rises in the mountains about 30 miles south of the Pennsylvania-West Virginia line, flows northwestward about 85 miles, and enters the Monongahela at McKeesport, Pa. Its chief tributary is the Casselman, which enters from the east, at Confluence, Pa. The basin is mountainous and quick spilling, without storage. The stream bed is steep and rocky and the flow rapid.

The following table gives the daily flow just below the mouth of the Casselman at Confluence, Pa., of all the large floods from 1874 to 1905:

Flood flow of Youghiogheny River at Confluence, Pa., 1874–1905.[a]

[Drainage area, 782 square miles. Lowest stage, −0.8 foot. Danger line, 10 feet.]

Year.	Date.	Gage height.	Discharge.	Year.	Date.	Gage height.	Discharge.
		Feet.	*Second-feet.*			*Feet.*	*Second-feet.*
1874	December 28	8.5	17,320	1891	February 16	6.9	....
	December 29	13.2	30,420		February 17	12.3	27,720
	December 30	6.1	....		February 18	10.2	21,750
1875	July 28	3.0	....		February 19	6.9	....
	July 29	10.7	23,100	1895	January 7	8.5	17,320
	July 30	5.2	....		January 8	10.8	23,370
	August 1	5.4	....		January 9	7.3	....
	August 2	12.3	27,720	1896	March 29	7.6	....
	August 3	10.3	22,020		March 30	10.5	22,560
	August 4	6.8	....		March 31	8.9	18,340
1876	September 17	4.4	....		July 24	5.4	....
	September 18	11.6	25,630		July 25	13.0	29,820
	September 19	7.6	....		July 26	5.9	....
1877	November 23	2.2	....	1897	February 21	5.8	....
	November 24	11.6	25,630		February 22	11.6	25,630
	November 25	7.8	....		February 23	13.0	29,820
1881	February 11	9.6	20,170		February 24	9.6	20,170
	February 12	11.6	25,630	1900	November 25	3.3	....
	February 13	9.4	19,640		November 26	10.3	22,020
1882	February 20	8.4	17,060		November 27	7.3	....
	February 21	10.5	22,560	1901	April 6	7.6	....
	February 22	8.3	16,810		April 7	10.5	22,560
1883	February 6	3.6	....		April 8	8.0	16,060
	February 7	13.8	32,220		December 14	2.6	....
	February 8	9.2	19,120		December 15	10.6	22,830
1888	August 21	17.0	42,000		December 16	7.0	....
			to 46,000	1902	February 27	4.0	....
1889	May 31	9.6	20,170		February 28	9.9	21,470
	June 1	12.0	26,820		March 1	10.1	20.960
	June 2	6.1	....	1904	January 22	9.0	18,600
1890	March 22	9.0	18,600		January 23	10.6	22,830
	March 23	10.9	23,650		January 24	5.0	....
	March 24	7.6	....	1905	March 21	8.0	16,080

[a] Gage heights from U. S. Weather Bureau records.

The largest flood on this stream in these thirty-one years occurred in August, 1888. The maximum rate of flow was then from 42,000 to 46,000 second-feet, or from 53.8 to 59 second-feet per square mile. Second in size to this flood was the spring flood of February 1883, when the maximum daily rate of flow was 41.2 second-feet per square mile.

TENNESSEE RIVER.

Tennessee River is formed by the junction of the French Broad and the Holston about 4 miles above Knoxville, Tenn. It is a long, somewhat U-shaped stream and is navigable to Chattanooga, a distance of 453 miles. The basin above Chattanooga is mountainous, being made up of a series of parallel ridges. The tributary streams drain the narrow valleys between these ranges. There is no surface and little ground storage, and the run-off is therefore very rapid.

The drainage area above Chattanooga, where the gaging station is located, is 21,380 square miles. The following table gives the daily rate of flow of this stream at Chattanooga during all the larger floods from 1867 to 1905.

Flood flow of Tennessee River at Chattanooga, Tenn., 1867–1905.[a]

[Drainage area, 21,382 square miles. Danger line, 33 feet gage height. Lowest stage, 0.0.]

Year.	Date.	Gage height.[b]	Discharge.	Year.	Date.	Gage height.[b]	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1867	March 11	58.0	[c]735,000	1897	March 14	37.9	363,200
1890	February 28	34.8	308,100		March 15	37.9	363,200
	March 1	40.2	404,200		March 16	37.0	347,200
	March 2	42.5	445,100		March 17	36.0	329,400
	March 3	41.0	418,400	1899	February 8	36.95	225,100
	March 4	34.4	300,900		February 9	38.25	333,200
1891	February 12	34.3	299,200		February 10	36.75	223,800
	February 13	36.5	338,300		March 17	36.90	224,800
	February 14	37.5	356,100		March 18	36.15	220,200
	February 15	35.5	320,500		March 19	35.85	218,300
	March 10	37.5	356,100		March 20	37.05	225,700
	March 11	38.9	381,000		March 21	39.20	239,000
	March 12	37.6	357,900		March 22	40.00	244,000
1892	January 16	37.1	349,000		March 23	38.70	235,900
	January 17	37.9	363,200		March 24	32.70	198,700
	January 18	35.2	315,200	1901	December 30	32.00	202,200
	April 10	34.3	299,200		December 31	37.40	237,300
1893	February 20	33.4	283,200	1902	January 1	40.10	254,800
1896	April 4	38.8	379,300		January 2	40.80	259,400
	April 5	40.5	409,500		March 4	38.0	241,200
1897	February 26	34.8	308,100		March 5	35.9	227,600

[a] Description of station given in Water-Sup. and Irr. Paper No. 98, p. 255.
[b] U. S. Weather Bureau records.
[c] Two per cent added for overflow passing around gage.

The flood of March, 1867, on this river exceeded all floods in the preceding ninety[a] years. It was one great rise, due to a very great storm that extended over the whole drainage area. At noon on March 11 the stage was 58 feet above low water at Chattanooga. At Knoxville the stage was 12 feet above that of 1847. The loss of life and property in this valley was unparalleled.

Second in size was the flood from February 27 to March 5, 1890, which had a maximum rate on March 2 of 445,120 second-feet, or about 0.6 the rate of the flood of March, 1867.

ILLINOIS RIVER.

Illinois River is the largest tributary of the Mississippi above the Missouri. It is formed by the junction of the Kankakee and Desplaines rivers in northeast Illinois. The basin including these streams has an area of 29,013 square miles, and its width is about half its length. It is level or gently undulating land, with a deep, rich, loamy soil, and is nearly all under cultivation. From Lake Michigan to Lasalle the fall of the river is 141 feet, and from Lasalle to its mouth the fall is 33 feet. The Chicago Drainage Canal extends from Lake Michigan to Illinois River at Joliet, and through it passes into the river 3,000 to 5,000 second-feet of the water of Lake Michigan. A large part of the Kankakee River basin in Indiana is a swamp formed by a ledge of limestone crossing the valley near the State line. This swamp exerts a marked influence on the flood flow and also on the low-water flow of the river.

[a] Rept. Chief Engr. U. S. Army for 1875, p. 635.

The following table gives the daily rate of flow of Illinois River at Peoria, Ill., during larger floods from 1890 to 1905. The gage heights are readings of the United States Weather Bureau gage on a pile of the protecting work of pier of the Peoria wagon bridge.

Flood flow of Illinois River, Peoria, Ill., 1890 to 1905.[a]

[Drainage area, 15,700 square miles. Danger line, 14 feet. Lowest water, 2.6 feet.]

Year.	Date.	Gage height.[b]	Discharge.	Year.	Date.	Gage height.[b]	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1890	June 25	13.3	18,290	1899	March 22	15.1	23,330
1891	April 17	15.0	22,960	1900	March 16	19.9	43,560
	April 18	15.0	22,960		March 17	19.9	43,560
	April 19	15.0	22,960	1901	March 27	17.0	30,900
1892	May 6	18.9	39,120		March 28	17.2	31,760
	May 7	20.9	47,920		March 29	17.4	32,620
	May 8	21.5	50,480		March 30	17.6	33,480
	May 9	21.9	52,180		March 31	17.7	33,910
	May 10	21.3	49,620		April 1	17.6	33,480
	May 11	20.7	47,140		April 2	17.5	33,050
	May 12	20.0	44,000	1902	July 22	21.0	48,350
	May 13	19.9	43,560	1903	March 12	19.3	40,880
	May 14	19.4	41,330		March 12	19.3	40,880
1893	March 13	19.6	42,220	1904	March 28	[c d]21.8	57,500
1895	December 31	15.0	22,960	1905	March 8	[d]15.0	24,090
1897	March 24	18.3	36,500		May 19	[d]17.4	35,500
1898	March 31	19.3	40,880				

[a] Description of gaging station in Water-Sup. and Irr. Paper No. 128, p. 39.
[b] Heights on U. S. Weather Bureau gage.
[c] From March 24 to April 7 this stage was above 20 feet, and from January 22 to May 19 the stage did not fall below 13 feet.
[d] Heights on U. S. Geological Survey gage.

The largest flood on this stream in these sixteen years occurred March, 1904. The greatest stage was 21.8 feet, or 19.2 feet above low water, and the greatest rate of flow was 57,500 second-feet, or 3.66 second-feet per square mile. For fifteen days during this flood the discharge did not fall below 44,000 second-feet.

Second in size was the flood of May, 1902, which had a maximum rate of 3.3 second-feet per square mile.

The floods on this stream are of long duration, but have a very small rate of flow.

MISSISSIPPI RIVER.

The Mississippi has its source in Itaska Lake, in northern Minnesota, at an elevation of 1,324 feet above sea level. From this lake to St. Paul, Minn., a distance of about 500 miles, it falls about 1,000 feet. The watershed is mostly hilly, without mountains, with considerable swampy land and lake surface. The surface covering is drift composed of sand, gravel, and bowlders. The total area above St. Paul is 36,085 square miles, 16,350 square miles of which is Minnesota River drainage.

The following table gives the daily stage and rate of flow of the larger floods from 1867 to 1904. The discharge is taken from a station rating table prepared from observations made by engineers of the United States Army in April and May, 1897. The daily rate of flow during the flood of 1881 is in doubt. It was less than 120,000 second-feet and greater than 95,000 second-feet.

Flood flow of Mississippi River at St. Paul, Minn., 1867–1904.[a]

[Drainage area, 36,085 square miles. Highest water, 19.7 feet, April 29, 1881; lowest, 0.9 foot, March 19, 1896. Danger line, 14 feet.]

Year.	Date.	Gage height.[c]	Discharge.	Year.	Date.	Gage height.[c]	Discharge.
		Feet.	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
1867	April 21	16.8	74,880	1882	April 13	13.3	....
	April 22	17.4	80,040	1883	April 25	12.2	....
	April 23	17.1	77,460	1884	May 5	10.2	....
	April 24	16.8	74,880	1885	June 18	7.4	....
	April 25	16.4	71,500	1886	March 29	8.2	....
	April 26	15.7	65,840	1887	April 17	9.6	....
	June 14	16.2	69,900	1888	April 14	14.4	....
	July 1	17.2	78,320	1889	May 21	4.5	....
	July 23	18.6	91,560	1890	April 13	5.5	....
1868	April 4	9.3	....	1891	April 17	6.4	....
1869	April 7	15.6	65,020	1892	May 26	12.6	....
	September 24–27	16.1	69,100	1893	May 5	14.7	....
[b]1872	May 19–22	7.7	....	1894	May 21	11.8	....
1873	April 29	16.0	68,300	1895	June 16	4.6	....
	June 1	15.7	65,840	1896	April 18	10.7	....
	June 13	15.5	64,200	1897	April 1	15.3	62,600
1874	July 1–2	11.6	....		April 2	16.4	71,500
1875	April 14	16.0	68,300		April 3	17.1	77,460
	April 15	17.0	76,600		April 4	17.4	80,040
	April 16	18.0	85,500		April 5	17.9	84,580
	April 17	17.8	83,640		April 6	18.0	85,500
	April 18	17.5	80,900		April 7	17.8	83,640
	April 19	17.0	76,600		April 8	17.7	82,700
	April 20	16.4	71,500		April 9	17.8	83,640
1876	May 22–23	10.4	....		April 10	17.7	82,750
1877	May 25	7.7	....		April 11	17.5	80,900
1878	April 27	6.7	....		April 12	17.1	77,460
1879	July 11	10.8	....		April 13	16.6	73,160
1880	June 17–18	15.2	61,800		April 14	16.2	69,900
1881	April 26	15.3	62,600		April 15	15.7	65,840
	April 27	17.9	84,580		April 16	15.2	61,800
	April 28	19.0	95,000	1898	June 8	10.7	....
	April 29	[d]19.5	to	1899	June 22	11.0	....
	April 30	19.3	120,000	1900	September 25–28	6.0	....
	May 1	18.7	92,620	1901	April 12	7.5	....
	May 2	17.8	83,640	1902	June 9	6.8	....
	May 3	16.3	70,750	1903	October 14	13.5	....
	May 4	15.8	66,660	1904	April 11	9.9	....

[a] Tabulated results of discharge observations Mississippi River and tributaries, 1897–98, p. 184.
[b] Records for 1870–71 missing.
[c] U. S. Weather Bureau gage records.
[d] Maximum, 19.7 feet.

The largest flood at St. Paul in these thirty-nine years was in April, 1881, when the rate of flow was from 2.63 to 3.33 second-feet per square mile. Second in size was the flood of July, 1867, which had a rate on the 23d of about 92,000 second-feet.

KANSAS RIVER.

The Kansas is formed by the junction of Republican and Smoky Hill rivers in central Kansas, flows eastward for a distance of 180 miles, and empties into Missouri River. The two streams that form the Kansas rise in the foothills of the Rocky Mountains, in eastern Colorado. The basin including these streams has a length of 490 miles, a width of 140 to 190 miles, and an area of 61,440 square miles. It is rolling prairie country, the eastern third being under cultivation, the remainder covered with tough buffalo grass sod. There is little timber and no surface storage. The surface falls gradually from an elevation of about 5,500 feet to 750 feet at the mouth of the stream. The mean annual precipitation varies from about 12 inches in the western part to 35 or 40 inches in the eastern part. The river bottom ranges in width from 1 to 4 miles and is almost entirely submerged during the largest floods, the natural channel being entirely inadequate to pass the flood flow, the average slope of stream bed being only 1.8 feet per mile.

The following table gives the daily rate of flow of Kansas River at Lawrence or Lecompton, Kans., during the larger floods from 1881 to 1905:

Flood flow of Kansas River at Lawrence and Lecompton, Kans., 1881–1905.[a]

[Drainage area at Lawrence, 59,841 square miles; drainage area at Lecompton, 58,550 square miles.]

Year.	Date.	Discharge.	Year.	Date.	Discharge.
		Sec.-feet.			*Sec.-feet.*
1881	March 7	18,700	1895	August 19	17,390
1882	April 10	19,370	1896	July 20	53,300
1883	June 25	19,370	1897	April 26	67,700
1886	May 10	19,370	1898	June 10	28,990
1889	May 13	24,340	1899	July 8	[b] 30,250
	July 22	24,340	1900	March 10	[b] 24,900
1891	June 1	35,600	1901	April 14	[b] 25,000
1892	May 16	67,700	1902	July 15	[b] 81,400
1893	June 5	19,370	1903	May 31	[b] [c] 221,000
	June 25	26,620	1904	July 7	[b] 130,000
1895	June 10	17,390	1905	September 18	[b] 56,000

[a] This station is described in Water-Sup. and Irr. Paper No. 99, p. 208.
[b] At Lecompton, Kans.
[c] From May 28 to June 7 the discharge was above 100,000 second-feet.

The largest flood during this period occurred in May and June, 1903. It is fully described in Water-Supply Paper No. 96. The maximum daily rate of flow was 221,000 second-feet, or 3.78 second-feet per square mile. Although this rate is very small as compared with that of eastern streams of the same drainage, it was an exceedingly large flood for this stream and caused the loss of $22,000,000 worth of property in Kansas and at Kansas City, Mo.

During this flood the greatest daily rate of flow of Blue River, one of the tributaries of the Kansas, was 7.2 second-feet per square mile.

The spring floods in this basin, due to melting snow, are small compared with those that occur in May, June, and July.

In 1844 there was a flood in this basin that is said to have equaled or exceeded that of 1903, but there is little data concerning this flood.

RIO GRANDE.

The Rio Grande rises in the Rocky Mountains in the southern part of Colorado, flows in a southerly direction through New Mexico, in a southeasterly direction through Texas, and empties into the Gulf of Mexico. The basin above San Marcial is long and comparatively narrow and its area above the gaging station at that place is 28,067 square miles. The slopes are steep, bare, and impervious, with no surface storage. The precipitation is small and generally torrential, except that which falls as snow at the headwaters of the streams.

The following table gives the daily rate of flow of the Rio Grande at San Marcial, N. Mex., during the largest floods from 1895 to 1905:

Flood flow of the Rio Grande at San Marcial, N. Mex. 1895 to 1905.[a]

[Drainage area, 28,067 square miles.]

Year.	Date.	Discharge.	Year.	Date.	Discharge.
		Sec.-feet.			*Sec.-feet.*
1895	April 15	7,800	1904	October 1	8,550
1896	April 29	4,800		October 2	18,400
	May 15	4,800		October 3	19,700
1897	May 21	21,750		October 4	5,000
	June 3	10,750		Ocober 9	12,000
1898	April 30	11,300		October 10	24,000
	July 17	16,775		October 11	33,000
1899	July 20	4,655		October 12	24,800
1900	May 22	6,250		October 13	21,750
	September 9	8,500		October 14	15,900
1901	May 25	5,600	1905	May 23	28,600
1902	August 26	10,500		May 24	29,070
1903	June 18	18,880		May 25	23,540
1904	September 29	3,280		May 26	28,000
	September 30	7,550			

[a] A description of this gaging station is given in Water-Sup. and Irr. Paper No. 99, p. 382.

NOTE.—The discharge was zero during the months of July, August, and part of September, 1900.

The greatest rate of flow during this period was in October, 1904. The mean rate for October 11 was 33,000 second-feet, or 1.17 second-feet per square mile. This flood is described in Water-Supply Paper No. 147, pages 143 to 150.

Second in size to this was the flood of May, 1905, described on pages 34 to 38 of this paper. The maximum rate of flow was 1.04 second-feet per square mile.

WESTERN STREAMS.

The maximum rate of discharge of some of the important streams in the arid region is given in the following table:

Maximum rate of flow of certain western streams, by years, 1886–1905.

[Drainage areas above gaging stations, in square miles: Colorado, 37,000; Loup, 13,540; Platte, 56,870; Arkansas, 4,600.]

Year.	Colorado River at Austin, Tex.		Loup River at Columbus, Nebr.		Platte River at Columbus, Nebr.		Arkansas River at Pueblo, Colo.	
	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Month.	Discharge.
		Sec.-feet.		*Sec.-feet.*		*Sec.-feet.*		*Sec.-feet.*
1886							May	7,660
1887							July	6,510
1888							June	[b] 2,760
1889							August	[b] 2,620
1890							May	[b] 3,270
1891							June	[b] 4,230
1892							June	[b] 4,750
1893							June	[b] 4,750
1894							June	
1895			June 3	9,100	June 1	27,200	July	5,000
1896	October	14,100	June 6	[a] 70,000	June 10	14,900	August	3,440
1897	January 2	11,000	July	27,000	June	31,000	June	3,750
1898	June 16	29,000	June	6,670	June	24,600	July	5,390
1899	June 8	103,400	July	6,980	May	25,770	June	4,890
1900	April 7	123,000	June	14,300	May	35,400	June	6,980
1901	July 13	40,900	June	5,900	April	28,400	May	11,060
1902	July 28	31,250	July	10,900	May	13,800	August	8,320
1903	February 27	32,500	August	20,000	May	21,600	June	6,100
1904	June 8	46,140	June	20,000	June	18,190	June	3,310
1905	April	51,190	July	25,800	June	51,100	June	6,460

[a] Mean rate from 7 p. m. June 6 to 2 a. m, June 7.
[b] At Canyon, Colo.

Maximum rate of flow of certain western streams, by years, 1886-1905—continued.

[Drainage areas above gaging stations, in square miles: Bear, 6,000; Humboldt, 10,780; Boise, 2,450; Weiser, 894.]

Year.	Bear River at Collinston, Utah.		Humboldt River at Golconda, Nev.		Boise River at Boise, Idaho.		Weiser River at Weiser, Idaho.	
	Month.	Discharge.	Month.	Discharge.	Month.	Discharge.	Month.	Discharge.
		Sec.-feet.		*Sec.-feet.*		*Sec.-feet.*		*Sec.-feet.*
1890	May	8,220						
1891	May	5,000						
1892	May	6,260						
1893	May	6,470						
1894	May	7,900						
1895	May	5,000			May	7,100	March	6,130
1896	May	5,650	June	1,614	June	40,130	May	17,940
1897	May	10,590	May	3,100	April	28,570	April	17,180
1898	June	5,320	March	485	May	8,250	April	3,880
1899	June	6,640	May	2,230	May	19,050	March	6,580
1900	May	4,650	June	464	May	11,960	March	8,120
1901	May	4,950	March	3,080	May	12,670	February	7,140
1902	June	3,340	June	523	May	8,190	February	7,340
1903	May	3,350	June	740	June	16,750	March	10,410
1904	May	6,700	April	1,060	April	19,680	March	11,620
1905	May	2,760	May	356	June	6,260		

[Drainage areas above gaging stations, in square miles: Tuolumne, 15 000, Kern, 2 345; Kings, 1,742.]

Year.	Tuolumne River at Lagrange, Cal.		Kern River at Rio Bravo ranch, Cal.		Kings River at Sanger, Cal.	
	Month.	Discharge.	Month.	Discharge.	Month	Discharge.
		Sec.-feet.		*Sec.-feet*		*Sec.-feet.*
1889						
1890						
1891						
1892						
1893						
1894			May	2,210		
1895			May	5,380		
1896	March	11,800	June	3,610	May	22,100
1897	May	14,700	May	5,340	May	22,730
1898	April	7,800	April	1,340	April	7,820
1899	March	21,800	March	4,930	March	20,200
1900	November	14,440	May	1,970	November	15,700
1901	February	19,240	May	4,420	January	43,930
1902	April	12 630	April	3,760	April	26,380
1903	April	20,340	May	3,374	May	17,290
1904	May	17,850	June	3,170	May	15,700
1905	March	13,070	June	3,039	June	9,795

FLOOD-FLOW CHARACTERISTICS.

The flood-flow data on pages 56 to 85 are summarized in the following table, which gives the drainage area in square miles of each river basin above the place of measurement; the length of record, or number of years that flood observations have been made; the largest daily rate of flow during the period of observation; the largest range of stage during that period, and the number of times that floods of a given magnitude compared with the largest flood have occurred in the period. This comparison of magnitude is by rate of flow, not by stage, except in a few cases. The rate of flow per foot increase of stage is much greater for the higher stages than the lower ones, so that the frequency of the stage of from, say, 0.8 to 0.9 of the maximum stage is much greater than the frequency of the rate of flow of from 0.8 to 0.9 of the maximum rate of flow.

An examination of this table will show that the streams in certain sections have definite flood-flow characteristics. Streams Nos. 1 to 6 form a northern group. The larger floods on these streams all occur in the spring. They are due to the rapid melting of snow and are intensified at times by the formation of ice gorges. The depth of snow on the ground in the early spring and the rate at which it melts are the controlling flood factors on these streams. Floods due to rain alone are of about half the magnitude of the spring floods and of much shorter duration. The maximum rate of run-off of these streams is small (15 to 25 second-feet per square mile) compared with streams elsewhere of the same size of basin and depth of annual precipitation. Floods of the first or second magnitude (from 0.8 to 1 of the magnitude of the greatest recorded flood) may be expected to occur, on an average, once in twelve to fifteen years.

Streams Nos. 7 to 11 form a second group. The rate of flood flow is larger than that of the streams in group 1. Some of the large floods in the spring are due to melting snow and some are due entirely to rain. The summer floods are not so long in duration as the spring floods. Large floods in streams of this group are not so frequent as in those of group 1. They occur about once in twenty to forty years.

The length of record of the four southeastern streams (Nos. 12–15) is too short, except that of the Savannah, to include the largest flood. The range of stage is large. The frequency of occurrence and duration of floods are also large, because of sluggish flow. The largest flood occurred in the fall, and had a rate of flow somewhat less than the largest rate of flow in group 2.

The largest floods in the upper Ohio basin occur in the spring. Two exceptions are the flood of July, 1888, on the Monongahela, and that of August, 1888, on the Youghiogheny. They resemble somewhat those on streams of groups 1 and 2, but are more like the latter than the former.

The Illinois and upper Ohio rivers have a remarkably small rate of flood flow—less than $3\frac{1}{3}$ second-feet per square mile. The large floods occur in the spring. The largest flood on Grand River, Michigan,[a] in probably a century had a maximum daily rate of about 8 second-feet per square mile of drainage area.

Streams 23–28 are in the arid and semiarid regions, and their rate of flood flow is very small. Very large floods occur rarely on those streams, and are due to heavy rain. Ordinary floods generally occur in the spring, and are due to melting snow. An exception to this rule is shown by Kansas River. The two great floods on Kansas River were about sixty years apart.

Other less important facts can be seen from a study of the data.

---

[a] Water-Sup. and Irr. Paper No. 147, p. 40.

Data on flood flow of streams in the United States.

	Stream.	Place.	Drainage area, in square miles.	Length of record, in years.	Period of record.	Maximum daily rate, in second-feet, per square mile.	Range of stage, in feet.	Number of occurrences of magnitude of greatest rate of flow.			
								0.6 to 0.7.	0.7 to 0.8.	0.8 to 0.9.	0.9 to 10.
1	Kennebec	Waterville, Me	4,380	12	1893-1904	25.4		3	2	0	1
2	Androscoggin	Rumford Falls, Me	2,320	12	1893-1904	23.8		1	1	0	1
3	Merrimac	Lawrence, Mass	4,553	59	1846-1904	18.0				1	3
4	Connecticut	Hartford, Conn	10,234	105	1801-1905	20.0				7	2
5	Hudson	Mechanicsville, N. Y	4,500	35	1869-1903	15.6				1	1
6	Genesee	Rochester, N. Y	2,428	119	1785-1903	19 to 22				1	1
7	Passaic	Dundee, N. J	8,227	26	1878-1903	42.5			1	0	1
8	Raritan	Boundbrook, N. J	806	96	1810-1905	64.5			2?	1?	1
9	Delaware	Lambertville, Pa	6,855	120	1786-1905	37.1			0	2	1
10	Potomac	Point of Rocks, Md	9,650	17	1889-1905	48.9		0	0	0	1
11	Susquehanna	Harrisburg, Pa	24,030	17	1889-1905	28 to 30.6			1	1	1
12	Cape Fear	Fayetteville, N. C	3,860	15	1889-1903	18 to 23	57.3	a 13	a 17	a 7	a 2
13	Savannah	Augusta, Ga	7,500	66	1840-1905	40.0	36.8	a 39	a 31	a 10	a 2
14	Alabama	Selma, Ala	15,400	14	1891-1904	9.5	58.9	a 6	a 10	a 6	a 3
15	Black Warrior	Tuscaloosa, Ala	4,900	17	1889-1905	32.0	64.8	a 10	a 11	a 12	a 8
16	Monongahela	Lock No. 4, Pa	5,430	20	1886-1905	38.1	38.8	3	1	0	1
17	Youghiogheny	Confluence, Pa	782	32	b 1874-1905	53.8 to 59.0	17.8	6	1	0	1
18	Allegheny	Freeport, Pa	9,220	31	c 1874-1904	d 26.7	37.5	a 65	a 17	a 7	a 4
19	Ohio	Wheeling, W. Va	23,800	22	1884-1905	20.8	53.4	3	5	1	1
20	Tennessee	Chattanooga, Tenn	21,382	38	1867-1904	34.4	58.0		0	0	1
21	Illinois	Peoria, Ill	15,700	16	1890-1905	3.3	19.3		2	2	3
22	Mississippi	St. Paul, Minn	36,085	38	1867-1904	3.3	19.0				3
23	Kansas	Lawrence, Kans	59,841	25	1881-1905	3.8	27.5	0	0	0	1
24	Rio Grande	San Marcial, N. Mex	28,067	11	1895-1905	1.17		1	0	1	1
25	Colorado	Austin, Tex	37,000	9	1896-1904	3.33		0	1	0	1
26	Loup	Columbus, Nebr	13,540	10	1895-1904	5.17		0	0	0	1
27	Arkansas	Pueblo, Colo	4,600	10	1895-1904	2.40		1	1	0	1
28	Bear	Collinston, Utah	6,000	15	1890-1904	1.76		3	2	0	1

a Number of occurrences of magnitude of greatest stage.
b Two years' records not complete.
c Three months of 1888 record missing.
d Maximum rate at Kittanning during flood of March, 1905.

INDEX TO FLOOD LITERATURE.

The following index to flood literature in the United States has been compiled from the indexes of the principal publications that treat of the subject. The floods have been indexed by streams and by the principal places affected by the flood. Throughout the index an attempt has been made to distinguish between the descriptions of flood and the flood discharges. The index is not exhaustive, but comprises, it is believed, all important articles:

Mokawk River, N. Y., discharge in upper portion of basin of, Mar. 25, 26, 1904...Rept. State Eng. New York, 1904, pp. 388, 389

flood on, March, 1904............Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, p. 32; Rept. State Eng. New York, 1904, p. 77

Moose River, discharge of, at Ager's mill, April, 1869................Hydrology State of New York, 1905, p. 466

Morehead, Tex., discharge of Pecos River at, September and October, 1904 ....Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, pp. 133, 137

Neosho Rapids, Kans., flood at, June, 1904......Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, p. 89

Neosho River, Kans., discharge of, at Iola, greatest annual, July, 1904......Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, p. 86

flood on, at Chanute, 1904 ....Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, p. 91

at Emporia, June, 1904.........................Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, p. 90

at Fort Gibson, Ind. T., June, 1904...............Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, p. 91

at Humboldt, June, 1904.........................Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, p. 87

at Iola, June, 1904..Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, p. 85

levees on..............Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, p. 92

New Hartford, N. Y., discharge of Starch Factory Creek at, March, 1904...Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, p. 37

discharge of Sylvan Glen Creek at, March, 1904....Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, p. 37

New York, flood discharge of streams in........H. Doc. 149, 56th Congress, 2d session, pp. 790–816

Report of Water Storage Commission of.......Eng. News, vol. 49, 1903, pp. 115, 183

Nine Mile Creek, N. Y., discharge of, at Stittsville, August, 1898......Hydrology State of New York, 1905, p. 485

North Loup River, Nebr., discharge of, near St. Paul, 1896...18th Ann. Rept. U. S. Geol. Survey, pt. 4, pp. 177–179

Oakdale, Pa., flood near, June, 1904.......................Water-Supply Paper No. 14, U. S. Geol. Survey, 1905, p. 114

Ohio River, flood on, 1884...................................Eng. News, vol. 11, 1884

flood protection on......Mississippi and Ohio Rivers, by Charles Ellet, 1853, p. 298

floods, great, on........Rept. on Physics and Hydraulics of Mississippi River, p. 79

velocity of, on......Mississippi and Ohio Rivers, by Charles Ellet, 1853, p. 300

Oneida Creek, N. Y., discharge of, near Kenwood, 1891..............Hydrology State of New York, 1905, p. 459

discharge of, near Kenwood, 1892......................Water-Supply Paper No. 65, U. S. Geol. Survey, 1902, p. 111

Ontario Paper Mills, N. Y., discharge of Black River at, April, 1869...Water-Supply Paper No. 65, U. S. Geol. Survey, 1902, p. 105

Oriskany Creek, N. Y., discharge of, at Coleman, spring of 1888.......Hydrology State of New York, 1905, p. 485

discharge of, in 1904..............Rept. State Eng. New York, 1904, pp. 588, 592

Oroville, Cal., discharge of Feather River at, February and March, 1904...Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, p. 16

Osage River, Kans., flood on, June, 1904..................Water-Supply Paper No. 147, U. S. Geol. Survey, 1905, pp. 106, 107

Oswego River, N. Y., discharge of, at Fulton....Hydrology State of New York, 1905, p. 458

INDEX.

CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 162.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of United States, folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

Most of the above publications may be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they may be obtained, free of charge (except classes 2, 7, and 8), on application.
2. A certain number are delivered to Senators and Representatives in Congress, for distribution.
3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they may be had at slightly above cost.
4. Copies of all Government publications are furnished to the principal public libraries in the large cities throughout the United States, where they may be consulted by those interested.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. This paper is the seventeenth in Series M, the complete list of which follows. (PP=Professional Paper; B=Bulletin; WS=Water-Supply Paper.

SERIES M—GENERAL HYDROGRAPHIC INVESTIGATIONS.

WS 56. Methods of stream measurement. 1901. 51 pp., 12 pls.
WS 64. Accuracy of stream measurements, by E. C. Murphy. 1902. 99 pp., 4 pls.
WS 76. Observations on the flow of rivers in the vicinity of New York Cit, by H. A. Pressey. 1902. 108 pp., 13 pls.
WS 80. The relation of rainfall to run-off, by G. W. Rafter 1903. 104 pp.
WS 81. California hydrography, by J. B. Lippincott. 1903. 488 pp, 1 pl
WS 88. The Passaic flood of 1902, by G. B Hollister and M O. Leighton 1903. 56 pp., 15 pls.
WS 91. Natural features and economic development of the Sandusky, Maumee, Muskingum, and Miami drainage areas in Ohio, by B. H. Flynn and M. S. Flynn. 1904 130 pp
WS 92. The Passaic flood of 1903, by M. O. Leighton. 1904 48 pp, 7 pls.
WS 94. Hydrographic manual of the United States Geological Survey, prepared by E C. Murphy, J C. Hoyt, and G. B. Hollister. 1904 76 pp., 3 pls.
WS 95 Accuracy of stream measurements (second edition), by E C Murphy. 1904 81 pp., 13 pls.
WS 96. Destructive floods in the United States in 1903, by E C Murphy 1904 81 pp. 13 pls.
WS 106. Water resources of the Philadelphia district by Florence Bascom 1904 75 pp, 4 pls
WS 109. Hydrography of Susquehanna River drainage basin, by J. C Hoyt and R H Anderson. 1905. 215 pp 29 pls
WS 116 Water resources near Santa Barbara California, by J B Lippincott 1904 99 pp., 8 pls.
WS 147. Destructive floods in the United States in 1904, by E C Murphy and others 1905 206 pp., 18 pls
WS 150. Weir experiments, coefficients and formulus by R. E. Horton 1006. 189 pp. 38 pls
WS 162. Destructive floods in the United States in 1905 by E C. Murphy and others. 1906. 105 pp., 4 pls.

Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

JULY, 1906.

IRR 162—06—8